CE257 Data Communication and Networking

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CHARUSAT

CE257 Data Communication and Networking

Week 4 – Session 1

STUDENTS WILL LEARN

- Digital Transmission
  - DIGITAL-TO-DIGITAL CONVERSION
    - Line Coding & Schemes
- Analog to Digital Conversion
- Serial and Parallel communication

VARIOUS CONVERSION TECHNIQUE

Data	Signal	Approach
Digital	Digital	Encoding
Analog	Digital	Encoding
Digital	Analog	Modulation
Analog	Analog	Modulation

- What type of signals to use?
  - Each signal has its own characteristics
- Depends on situation and bandwidth available, we can select type of signal for transmission.

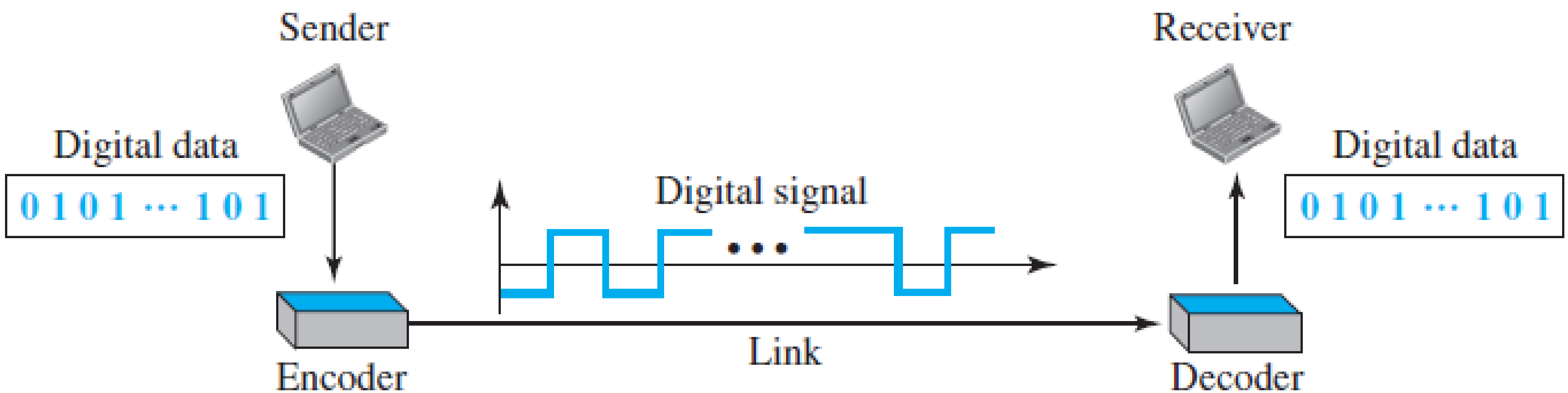
DIGITAL-TO-DIGITAL CONVERSION

- Digital data is converted into digital signal for transmission
- The conversion involves three techniques:
  - line coding,
  - block coding,
  - and scrambling.

DATA CHARACTERISTICS

LINE CODING

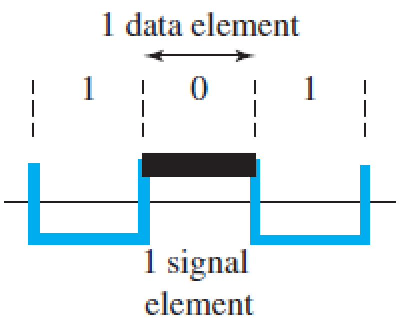
- **Line coding** is the process of converting digital data to digital signals
  - i.e. Line coding converts a sequence of bits to a digital signal.



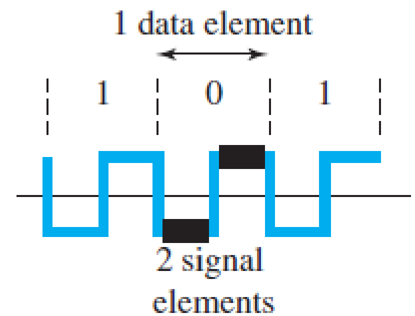
SIGNAL ELEMENT VERSUS DATA ELEMENT

- Goal
  - send data elements
- In digital data communications, a **signal element** carries **data elements.**
- **Data elements** are what we need to send; **Signal elements** are what we can send.
- We define a ratio *r* which is the number of data elements carried by each signal element.

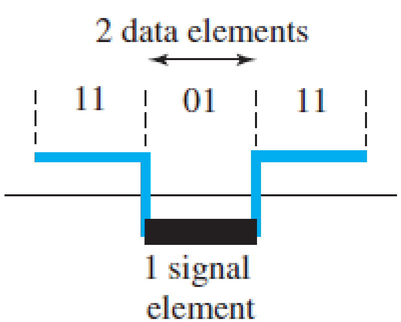
EXAMPLES



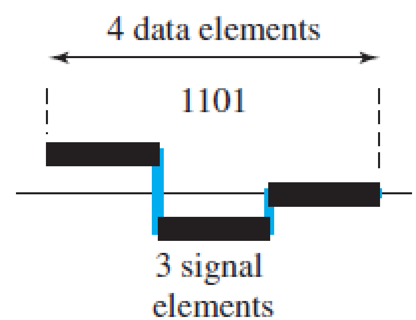
a. One data element per one signal element ($r = 1$)



b. One data element per two signal elements $\left(r = \frac{1}{2}\right)$



c. Two data elements per one signal element ($r = 2$)



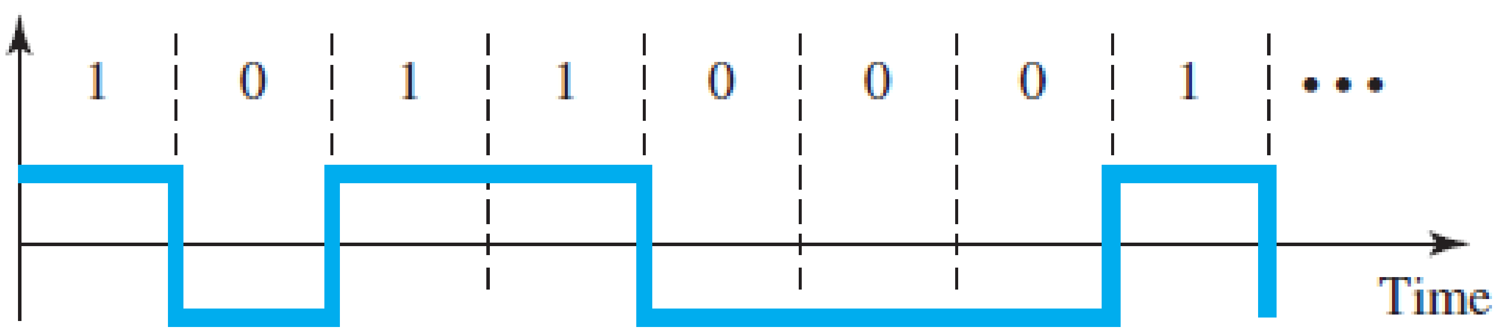
d. Four data elements per three signal elements $\left(r = \frac{4}{3}\right)$

DATA RATE VERSUS SIGNAL RATE

- The **data rate** defines the number of data elements (bits) sent in 1s.
  - unit is bits per second
- The **signal rate** is the number of signal elements sent in 1s.
  - unit is the baud
- One goal in data communications is to increase the data rate while decreasing the signal rate.
  - Increasing the data rate increases the speed of transmission
  - Decreasing the signal rate decreases the bandwidth requirement

DIGITAL SIGNAL TRANSMISSION

- Problems associated with digital transmission
  - Baseline Wandering
  - DC Components
  - Self-synchronization
  - Built-in Error Detection
  - Immunity to Noise and Interference
  - Complexity



a. Sent

BASELINE WANDERING/SKEWING

- In decoding a digital signal, the receiver calculates a running average of the received signal power. This average is called the ***baseline*.**
- The incoming signal power is evaluated against this baseline to determine the value of the data element. A long string of 0s or 1s can cause a drift in the baseline (**baseline wandering**) and make it difficult for the receiver to decode correctly. A good line coding scheme needs to prevent baseline wandering.

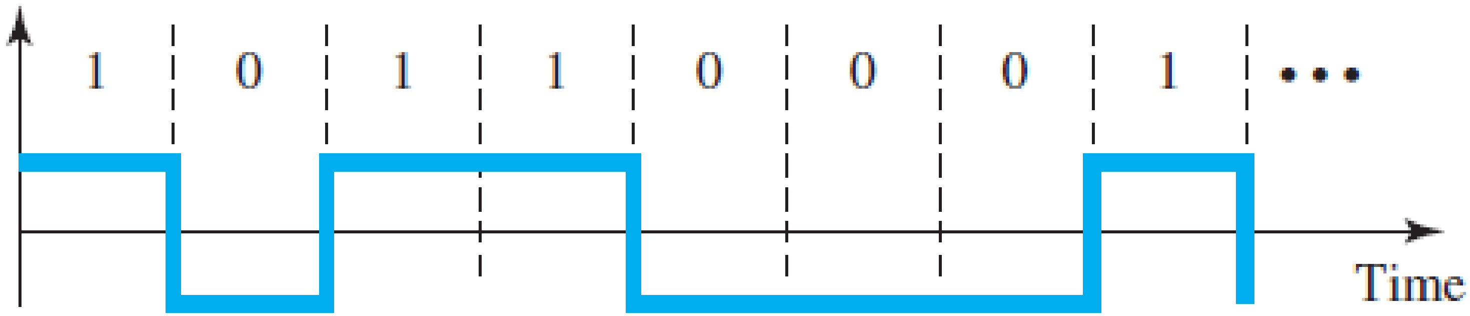
DC COMPONENTS

- When the voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies (results of Fourier analysis). These frequencies around zero, called DC (direct-current) *components*, present problems for a system that cannot pass low frequencies or a system that uses electrical coupling (via a transformer).
- We can say that DC component means 0/1 parity that can cause base-line wondering.
- Also a long-distance link may use one or more transformers to isolate different parts of the line electrically. For these systems, we need a scheme with no **DC component.**

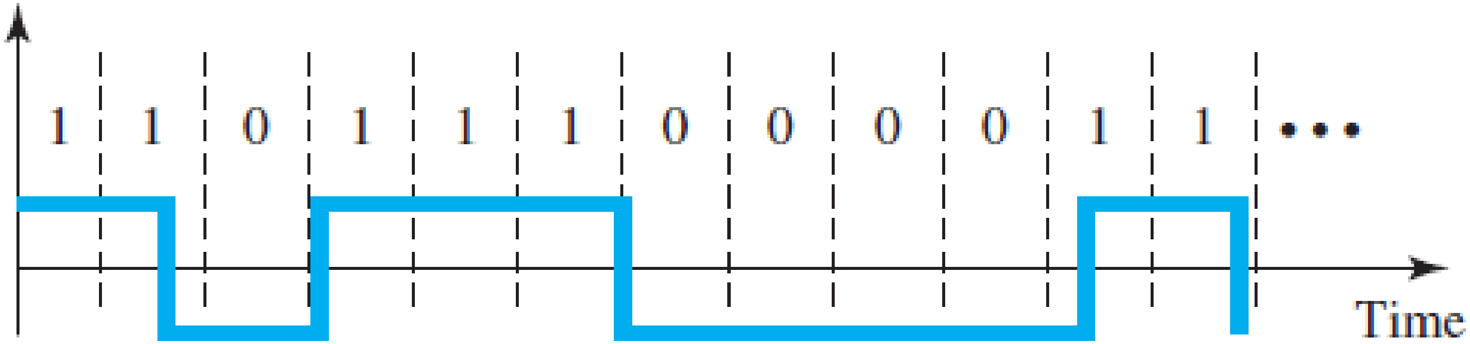
SELF-SYNCHRONIZATION

- To correctly interpret the signals received from the sender, the **receiver's bit intervals must correspond exactly to the sender's bit intervals.** If the receiver clock is faster or slower, the bit intervals are not matched and the receiver might misinterpret the signals.
- Figure shows a situation in which the receiver has a shorter bit duration. The sender sends 10110001, while the receiver receives 110111000011.

EXAMPLE

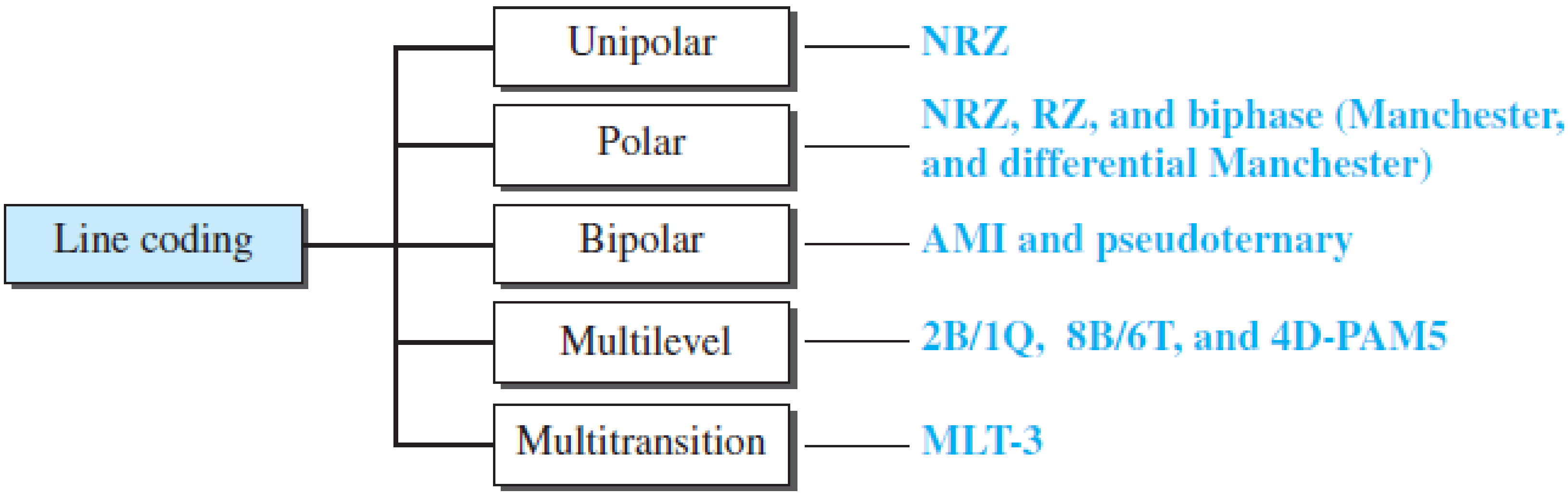


a. Sent

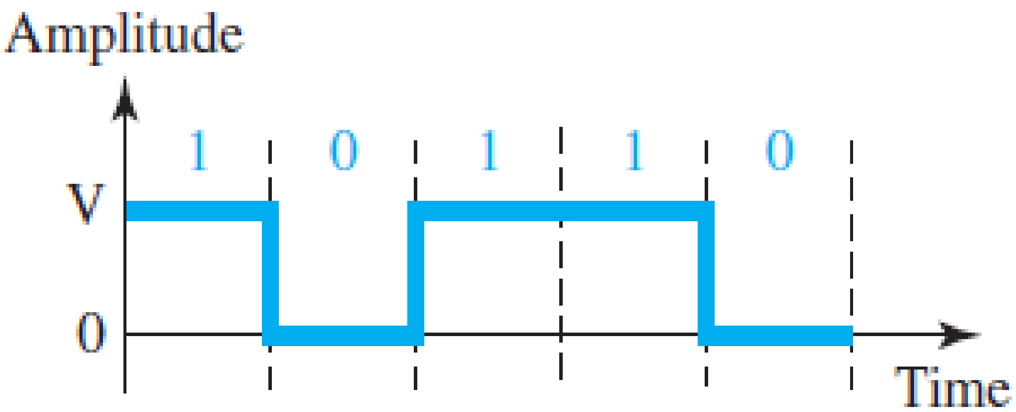


b. Received

LINE CODING SCHEMES



NRZ (NON-RETURN-TO-ZERO)

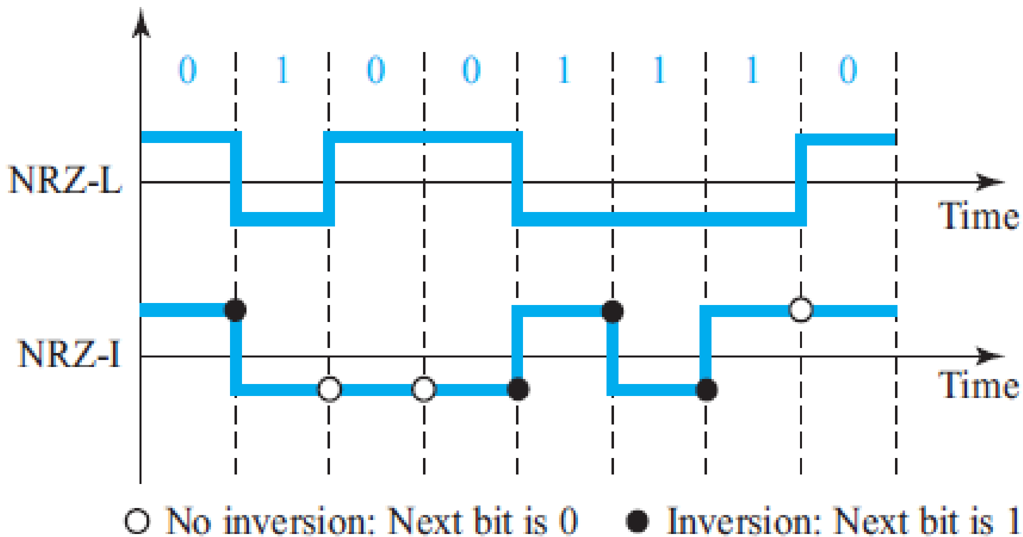


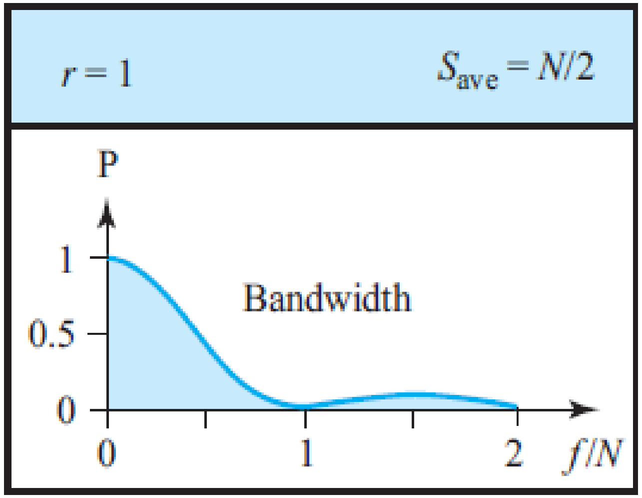
$$\frac{1}{2}V^2 + \frac{1}{2}(0)^2 = \frac{1}{2}V^2$$

Normalized power

NON-RETURN-TO-ZERO (NRZ)

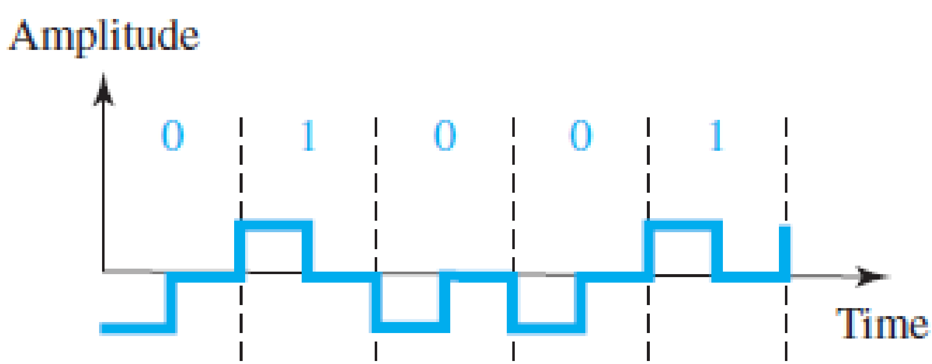
- Suffers from baseline wandering: If there is a long sequence of 0s or 1s in NRZ-L, the average signal power becomes skewed.
- NRZ-L and NRZ-I both have a DC component.
- Problem of Synchronization exists.

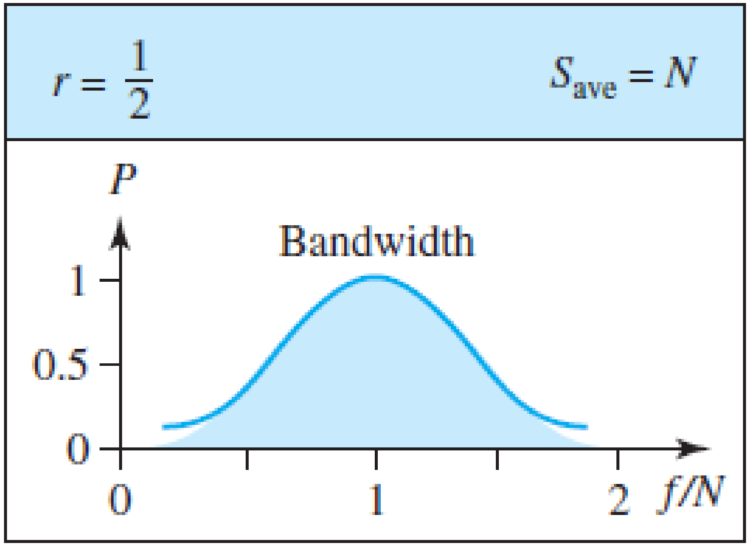




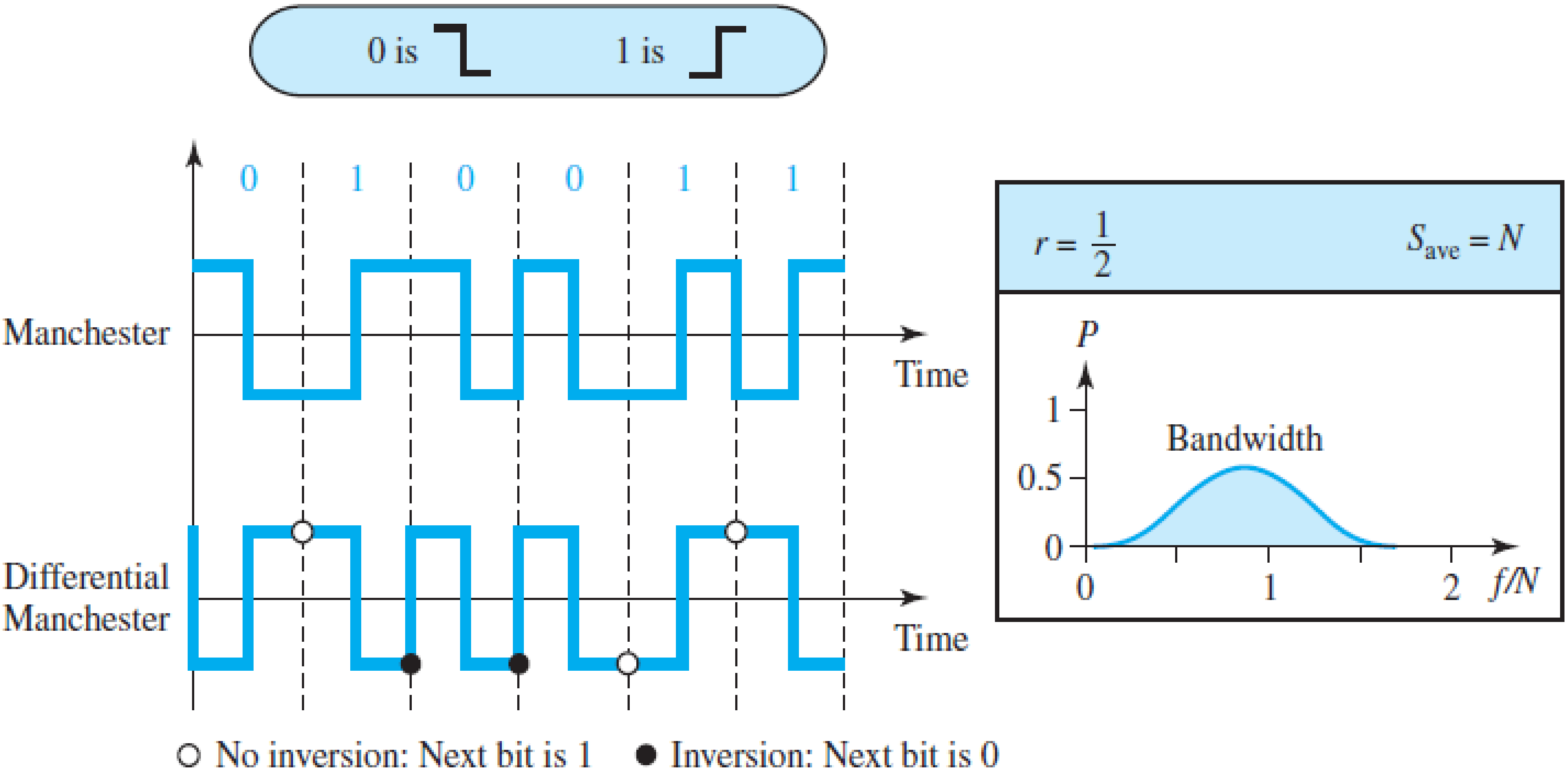
RETURN-TO-ZERO (RZ)

- RZ uses three levels of voltage
- Problems
  - Three levels of voltage which is more complex to create.
- Suffers from base line skew

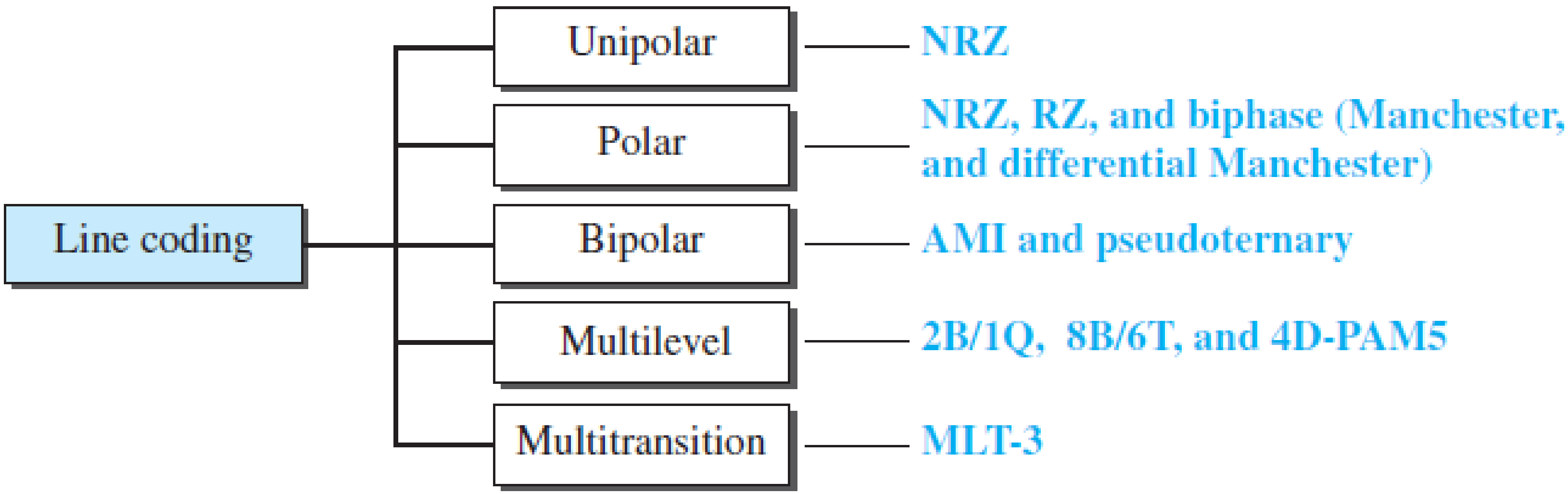




BIPHASE: MANCHESTER AND DIFFERENTIAL MANCHESTER



LINE CODING SCHEMES

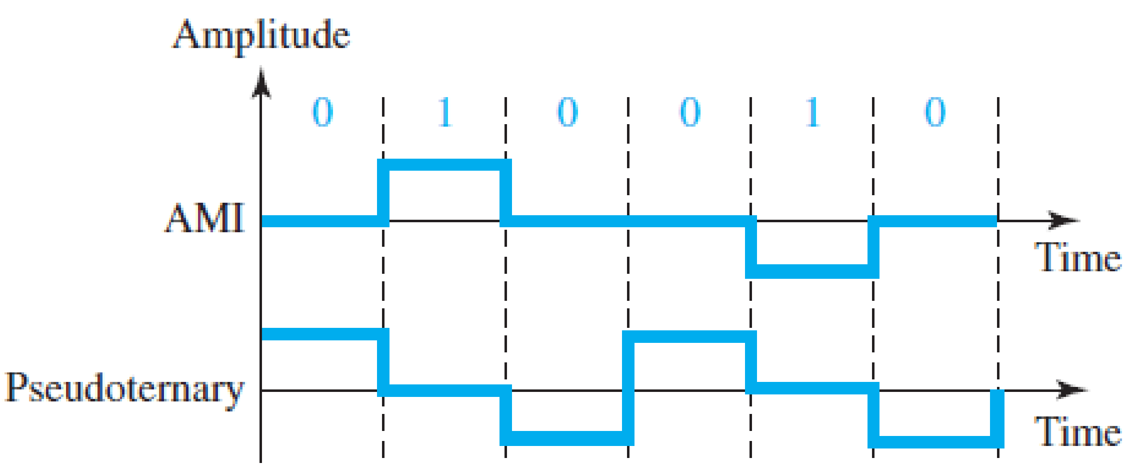


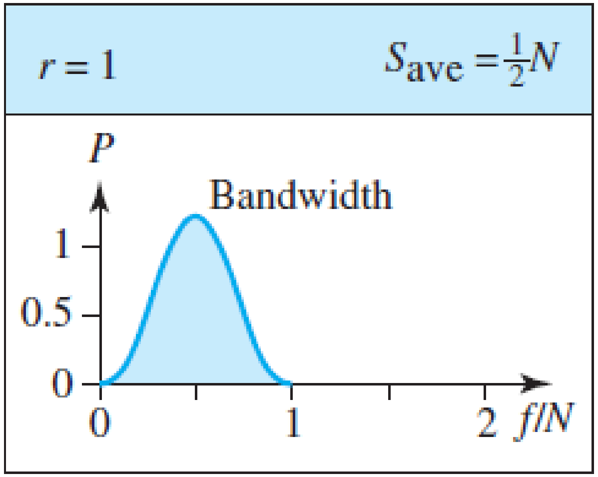
BIPOLAR SCHEMES

- In **bipolar** encoding (sometimes called *multilevel binary*), there are three voltage levels: positive, negative, and zero. The voltage level for one data element is at zero, while the voltage level for the other element alternates between positive and negative

AMI AND PSEUDOTERNARY

- The bipolar scheme has the same signal rate as NRZ, but there is no DC component.
- The NRZ scheme has most of its energy concentrated near zero frequency, which makes it unsuitable for transmission over channels with poor performance around this frequency.
- It is used for long-distance communication,
- It suffers from a synchronization problem when a long sequence of 0s is present in the data.





MULTILEVEL SCHEMES

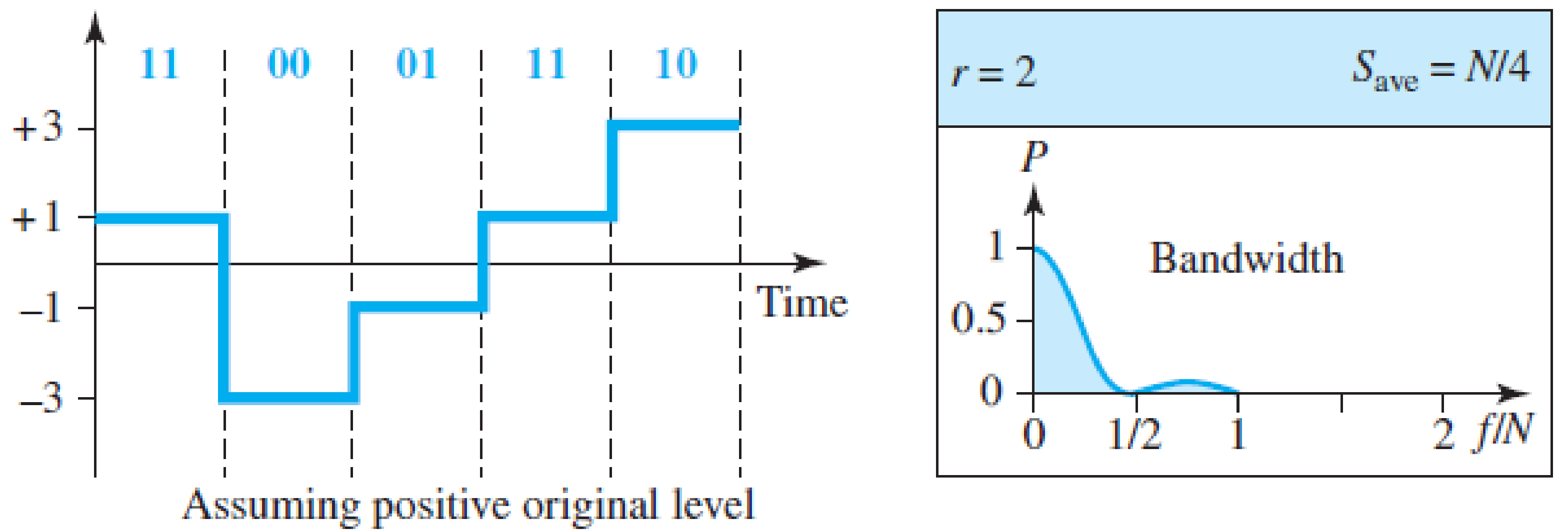
- The goal is to increase the number of bits per baud by encoding a pattern of *m* data elements into a pattern of *n* signal elements.
- The code designers have classified these types of coding as ***mBnL***,
  - where *m* is the length of the binary pattern, *B* means binary data, *n* is the length of the signal pattern, and *L* is the number of levels in the signaling.
- A letter is often used in place of *L*: *B* (binary) for *L* = 2, *T* (ternary) for *L* = 3, and *Q* (quaternary) for *L* = 4.

2B1Q

- The first *mBnL* scheme we discuss, **two binary, one quaternary (2B1Q),** uses data patterns of size 2 and encodes the 2-bit patterns as one signal element belonging to a four-level signal.

Rules:

00 → −3 01 → −1 10 → +3 11 → +1



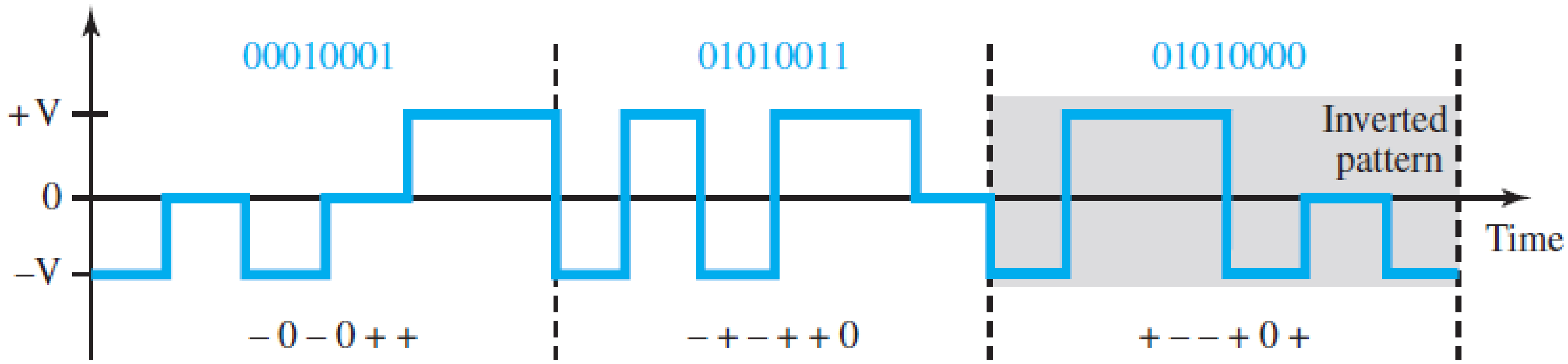
2B1Q

- The average signal rate of 2B1Q is $S = N/4$. This means that using 2B1Q, we can send data 2 times faster than by using NRZ-L.
- However, 2B1Q uses four different signal levels, which means the receiver has to discern four different thresholds.
- The reduced bandwidth comes with a price.
- There are no redundant signal patterns in this scheme because $2^2 = 4^1$.
- The 2B1Q scheme is used in DSL (Digital Subscriber Line) technology to provide a high-speed connection to the Internet by using subscriber telephone lines

8B6T

- A very interesting scheme is **eight binary, six ternary (8B6T).** This code is used with 100BASE-4T cable.
- The idea is to encode a pattern of 8 bits as a pattern of six signal elements, where the signal has three levels (ternary). In this type of scheme, we can have $2^8 = 256$ different data patterns and $3^6 = 729$ different signal patterns.
- The mapping table is shown in Appendix F. There are $729 - 256 = 473$ redundant signal elements that provide synchronization and error detection

8B6T


00010001
01010011
01010000
+V
0
–V
Inverted pattern
Time
– 0 – 0 + +
– + – + + 0
+ – – + 0 +

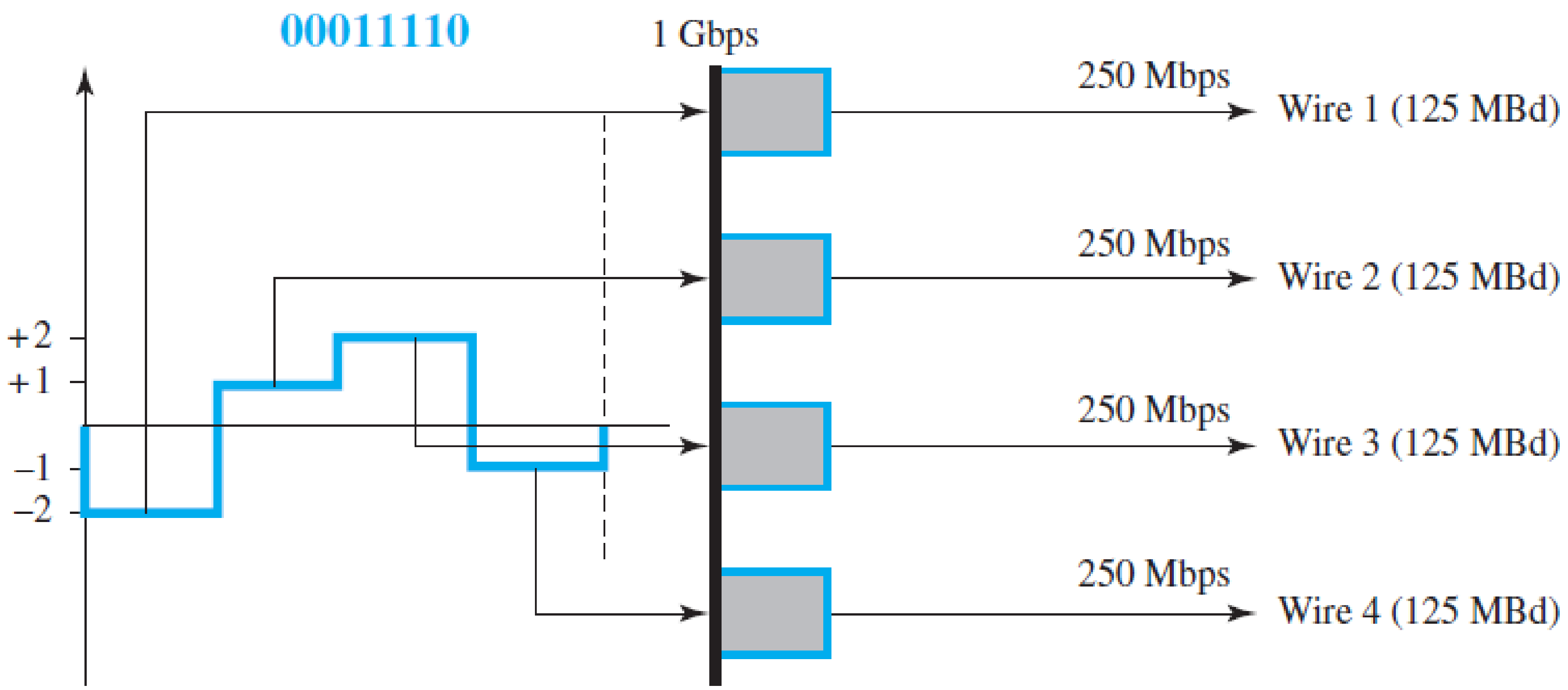
8B6T

- Each signal pattern has a weight of 0 or +1 DC values. This means that there is no pattern with the weight −1. To make the whole stream DC-balanced, the sender keeps track of the weight. If two groups of weight 1 are encountered one after another, the first one is sent as is, while the next one is totally inverted to give a weight of −1.
- The average signal rate of the scheme is theoretically $S_{ave} = 1/2 \times N \times 6/8$; in practice the minimum bandwidth is very close to $6N/8$.

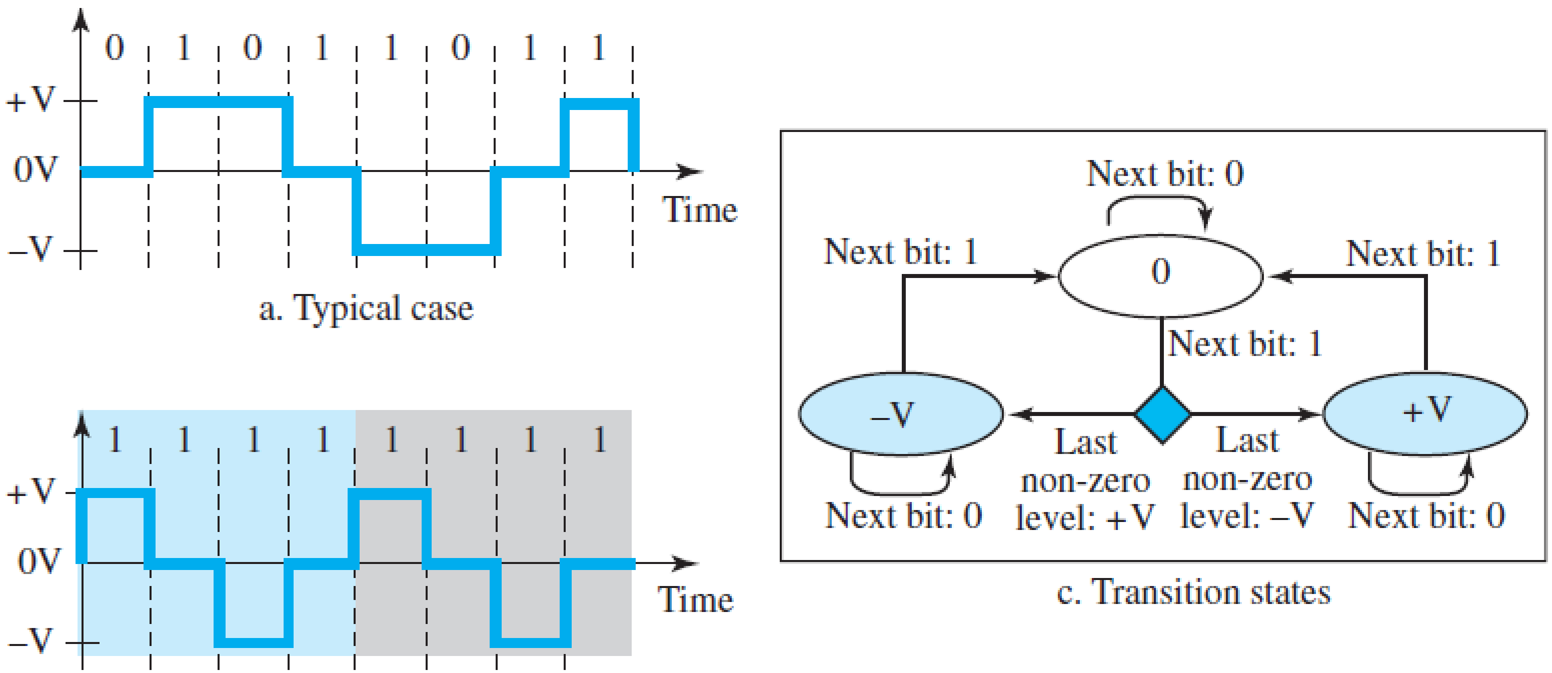
4D-PAM5

- four-dimensional five level pulse amplitude modulation (4D-PAM5)
- The 4D means that data is sent over four wires at the same time. It uses five voltage levels, such as −2, −1, 0, 1, and 2. However, one level, level 0, is used only for forward error detection

GIGABIT ETHERNET



MULTITRANSITION: MLT-3



a. Typical case

b. Worst case

c. Transition states

SUMMARY OF LINE CODING SCHEMES

Category	*Scheme*	*Bandwidth (average)*	*Characteristics*
Unipolar	NRZ	$B = N/2$	Costly, no self-synchronization if long 0s or 1s, DC
Polar	NRZ-L	$B = N/2$	No self-synchronization if long 0s or 1s, DC
	NRZ-I	$B = N/2$	No self-synchronization for long 0s, DC
	Biphase	$B = N$	Self-synchronization, no DC, high bandwidth
Bipolar	AMI	$B = N/2$	No self-synchronization for long 0s, DC
Multilevel	2B1Q	$B = N/4$	No self-synchronization for long same double bits
	8B6T	$B = 3N/4$	Self-synchronization, no DC
	4D-PAM5	$B = N/8$	Self-synchronization, no DC
Multitransition	MLT-3	$B = N/3$	No self-synchronization for long 0s

CE257 Data Communication and Networking

Week 6 – Session 1

STUDENTS WILL LEARN

- Digital Transmission
  - DIGITAL-TO-DIGITAL CONVERSION
    - Line Coding & Schemes
    - Block coding
    - Scrambling
- Analog to Digital Conversion
- Serial and Parallel communication

BLOCK CODING

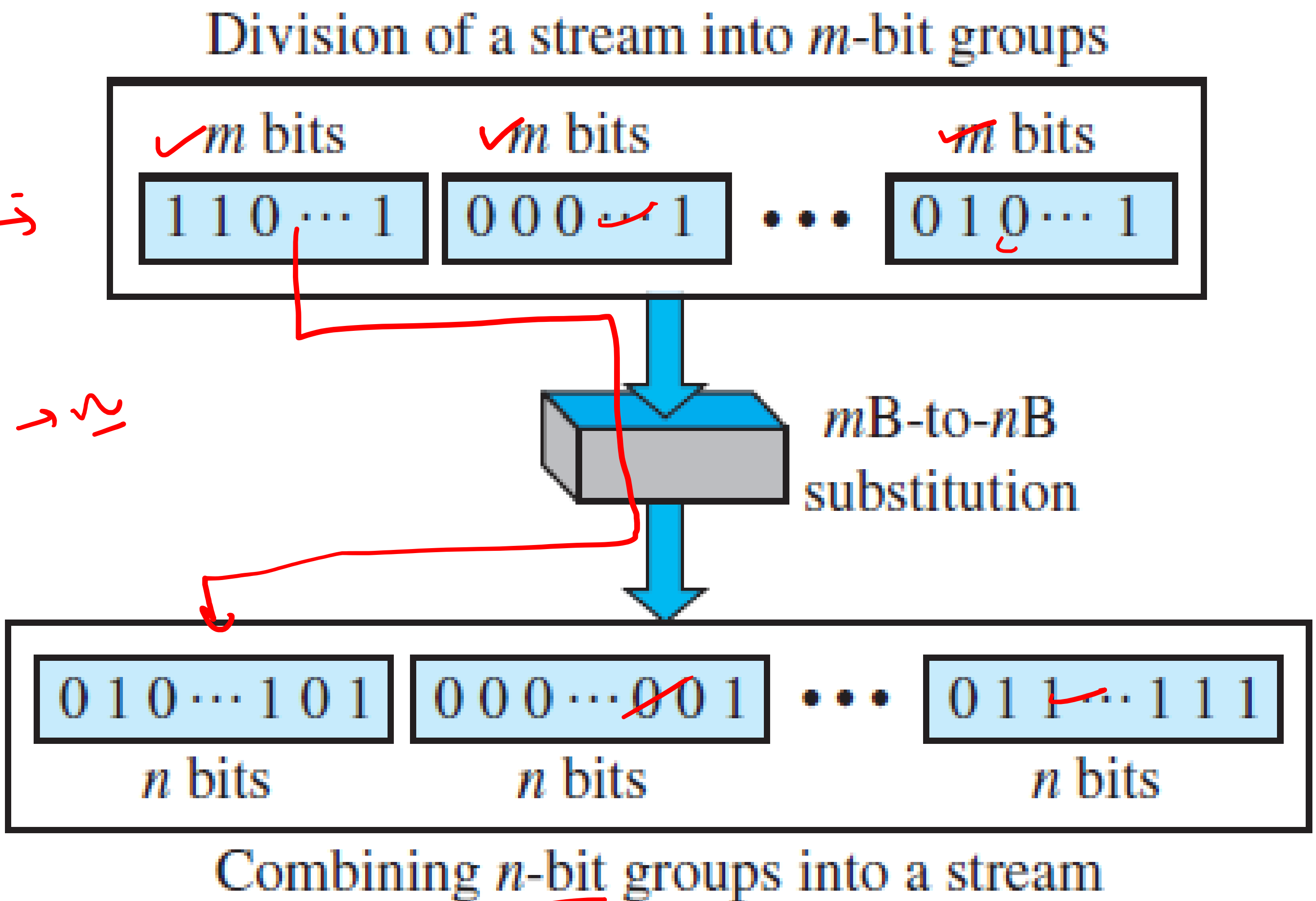
- Block coding ensures synchronization and to inherent error detecting
- In general, block coding changes a block of m bits into a block of n bits, where n is larger than m.
  - Block coding is referred to as an mB/nB encoding technique.

BLOCK CODING

- Block coding normally involves three steps: division, substitution, and combination.
- In the **division** step, a sequence of bits is divided into groups of *m* bits. For example, in 4B/5B encoding, the original bit sequence is divided into 4-bit groups.
- In **substitution** step, we substitute an *m*-bit group with an *n*-bit group.
  - For example, in 4B/5B encoding we substitute a 4-bit group with a 5-bit group.
- Finally, all group bits are **combined** to form a stream. The new stream has more bits than the original bits.

$m < n$

BLOCK CODING

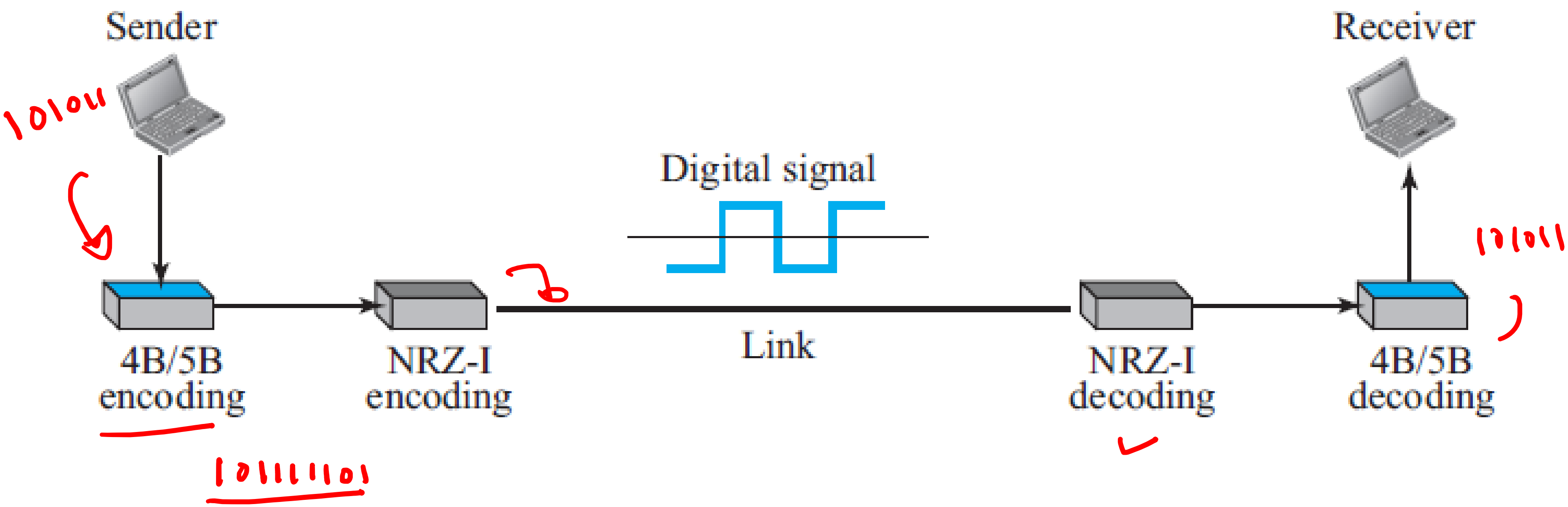


$m \to n$

4B/5B

- The **four binary/five binary (4B/5B)** coding scheme was designed to be used in combination with NRZ-I.
- 4B/5B overcomes synchronization problem
  - The 4B/5B scheme achieves this goal, by not to have more that three consecutive 0s

USING BLOCK CODING 4B/5B WITH NRZ-I LINE CODING SCHEME



ENCODING SEQUENCE

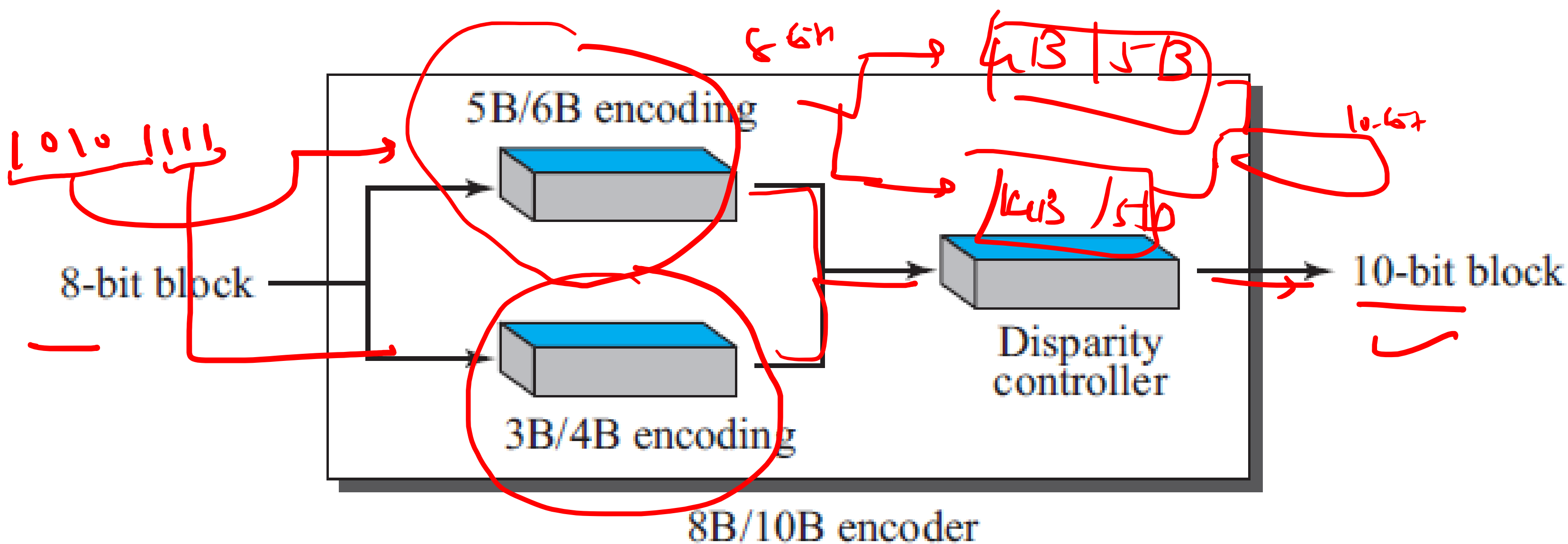
Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

1010 1110 1100

$\boxed{10110\ 11100\ 11010}$

8B/10B

- The **eight binary/ten binary (8B/10B)** encoding is similar to 4B/5B encoding except that a group of 8 bits of data is now substituted by a 10-bit code



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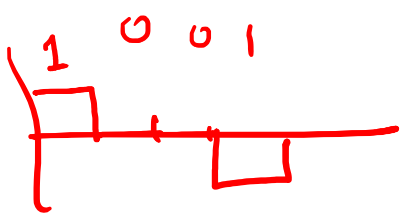
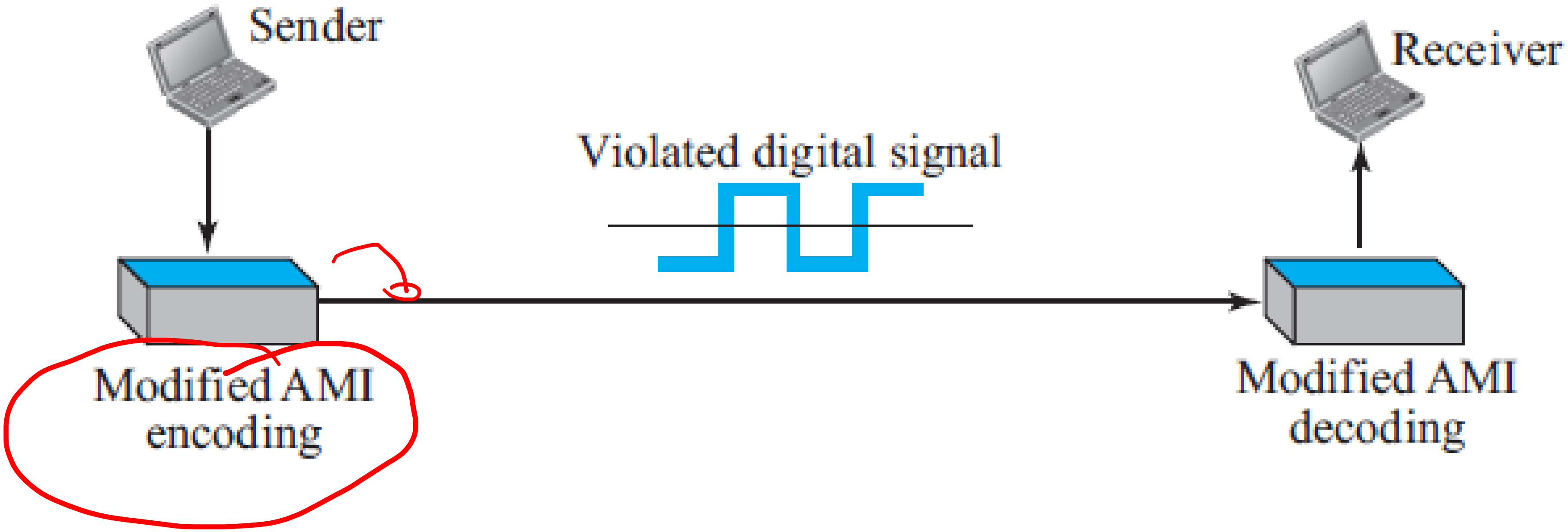
    - Block coding
    - Scrambling
  - ANALOG TO DIGITAL Conversion
- Serial and Parallel communication

SCRAMBLING

- In scrambling, long zero-level pulses are substituted with a combination of other levels to achieve synchronization for long distance.
- It modifies AMI rule to include scrambling.
- Two common scrambling techniques are B8ZS and HDB3.



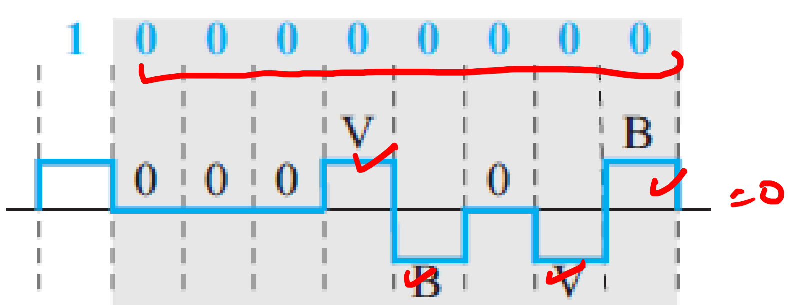
EXAMPLE


Sender
Receiver
Violated digital signal
Modified AMI encoding
Modified AMI decoding

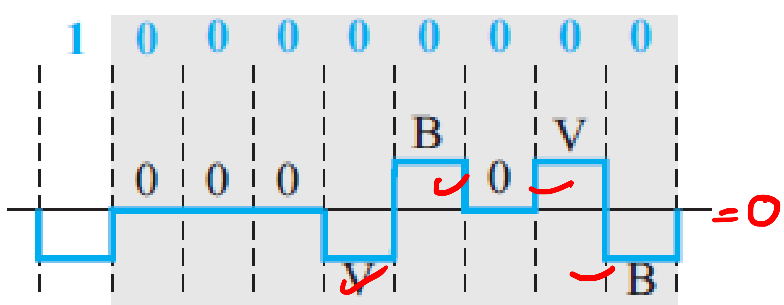
B8ZS

- Bipolar with 8-zero substitution (B8ZS) is commonly used in North America.
- B8ZS substitutes eight consecutive zeros with 000VB0VB.

8-C.



a. Previous level is positive.



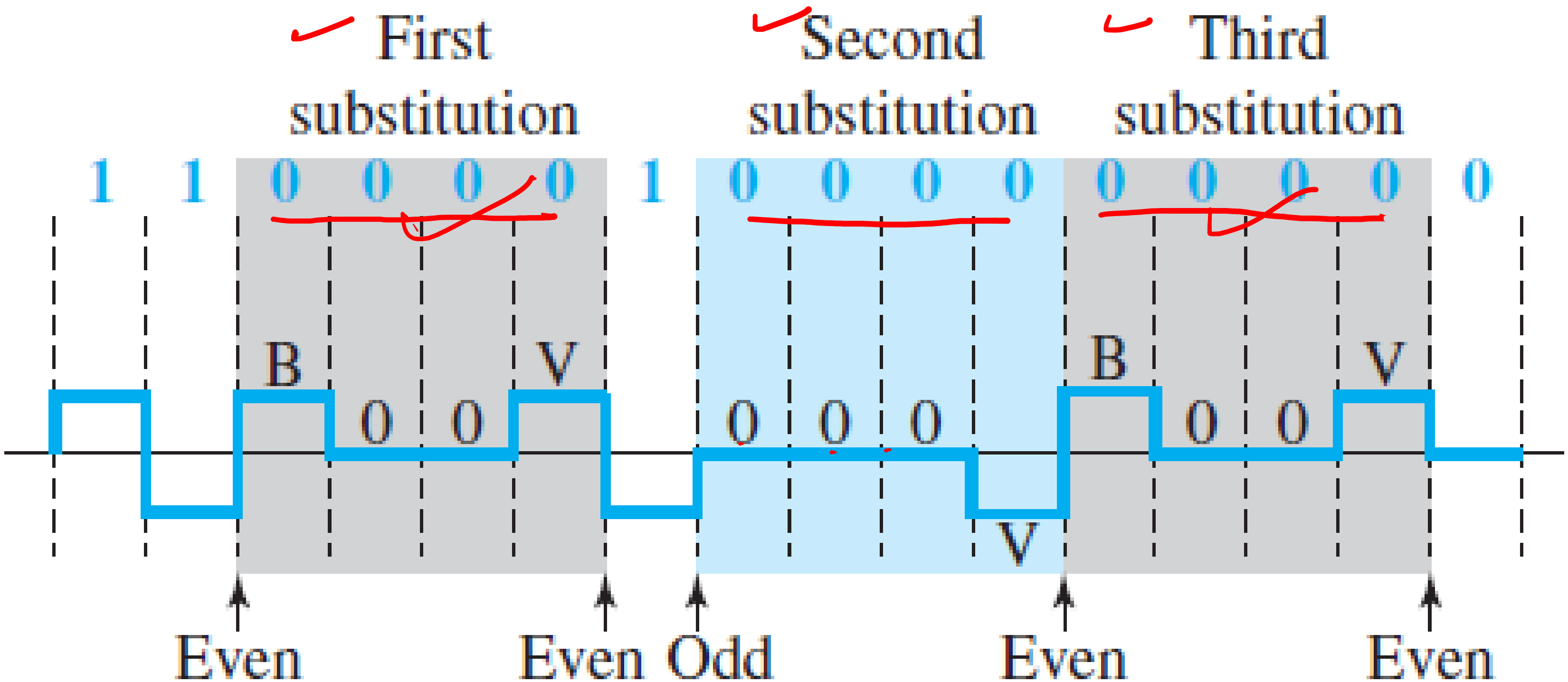
b. Previous level is negative.

HDB3

- **High-density bipolar 3-zero (HDB3)** is commonly used outside of North America.
- four consecutive zero-level voltages are replaced with a sequence of **000V** or **B00V.**
  - **1.** If the number of nonzero pulses after the last substitution is odd, the substitution pattern will be **000V**, which makes the total number of nonzero pulses even.
  - **2.** If the number of nonzero pulses after the last substitution is even, the substitution pattern will be **B00V**, which makes the total number of nonzero pulses even.

HDB3

- HDB3 substitutes four consecutive zeros with 000V or B00V depending on the number of nonzero pulses after the last substitution.



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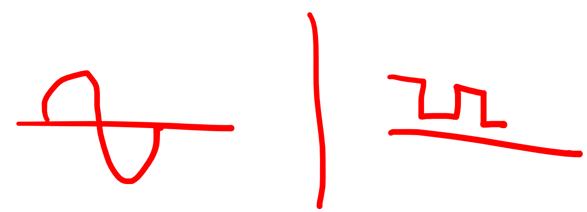
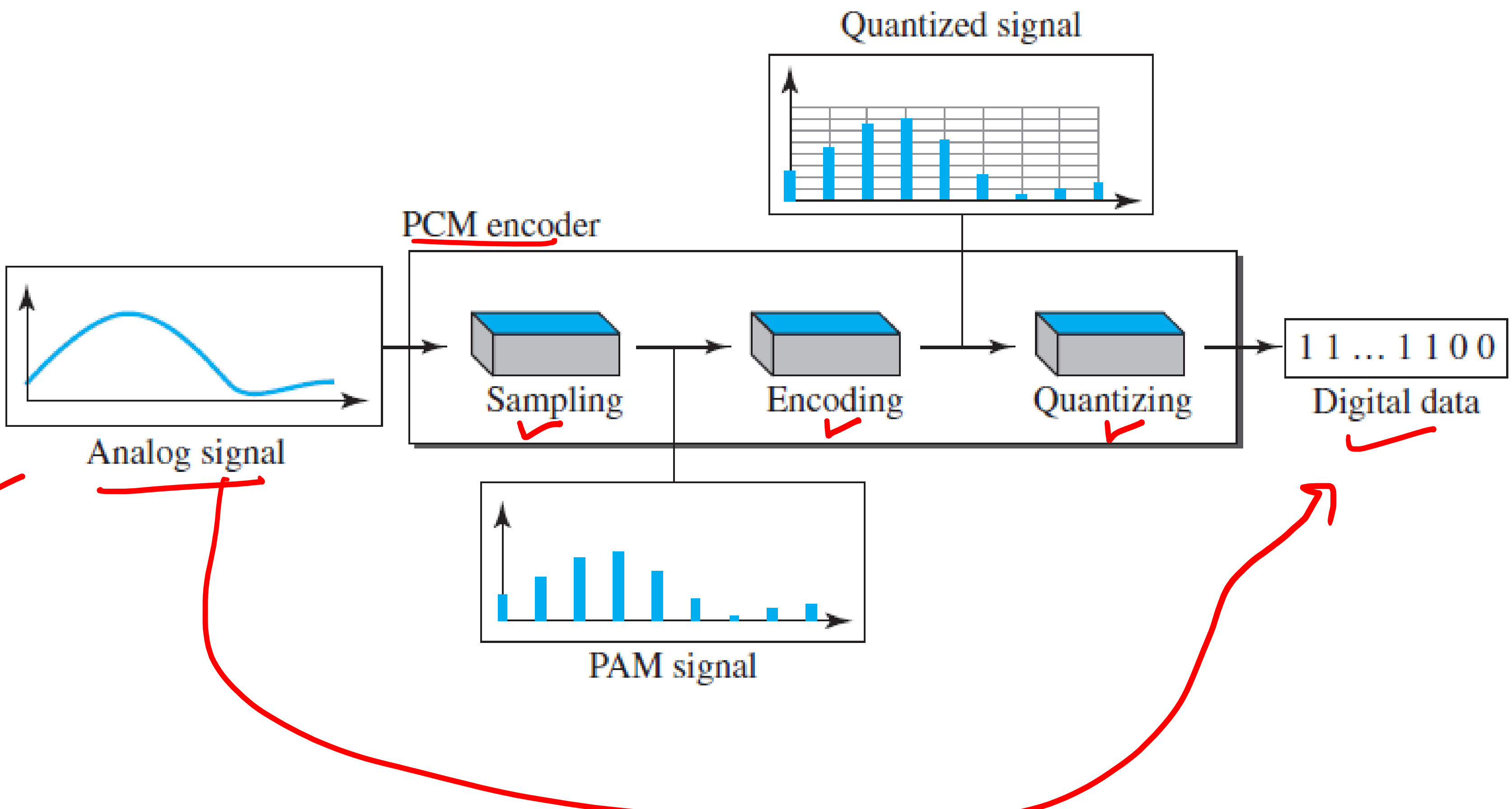


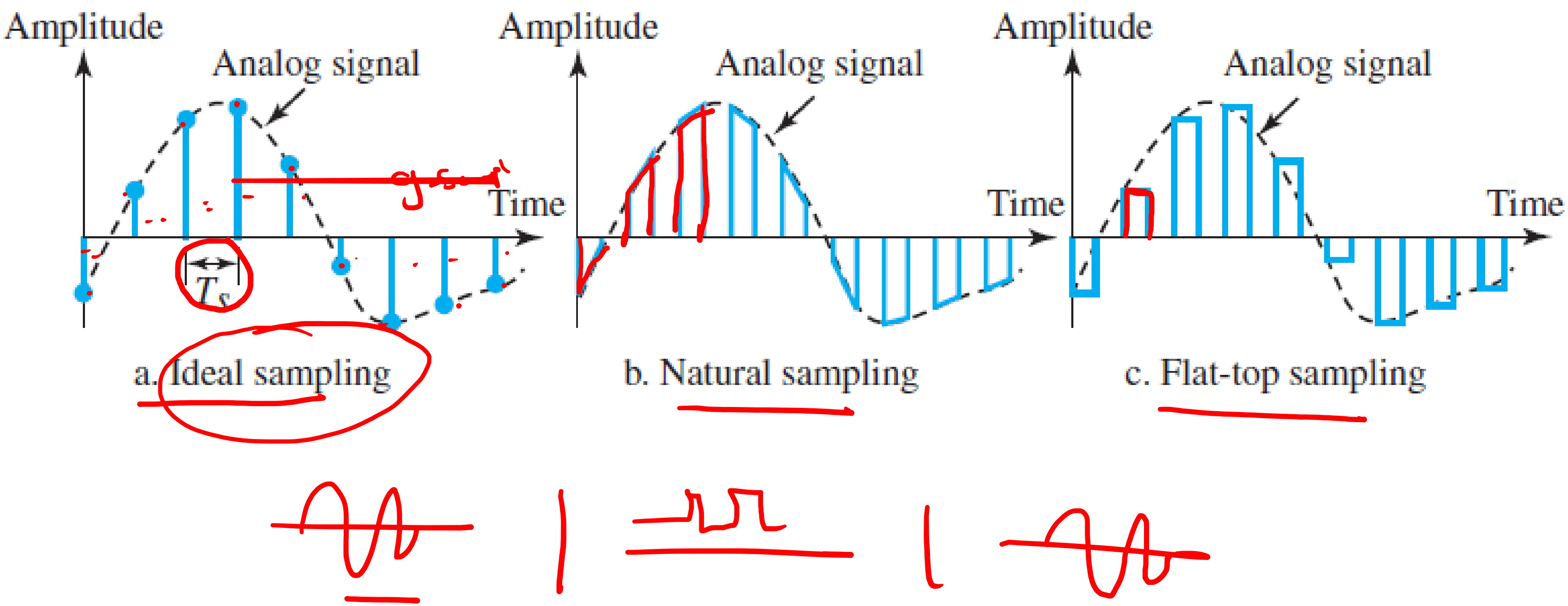
ANALOG-TO-DIGITAL CONVERSION

- Pulse Code Modulation (PCM)



SAMPLING

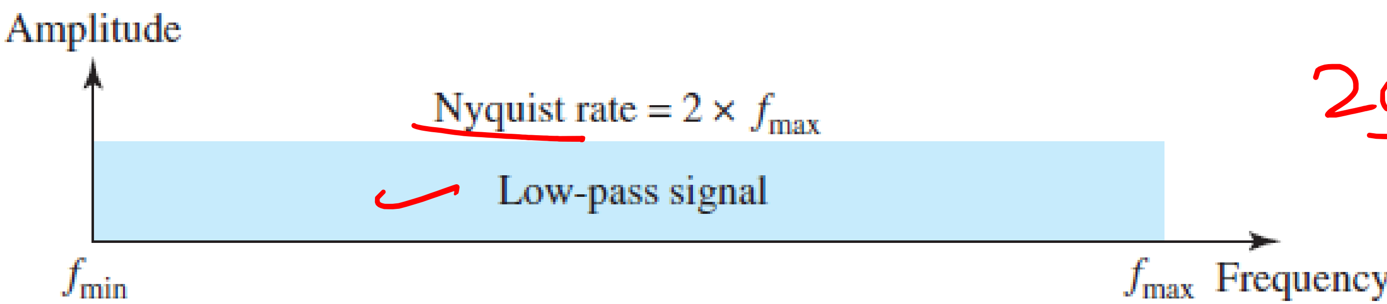
- *Three different sampling methods for PCM*



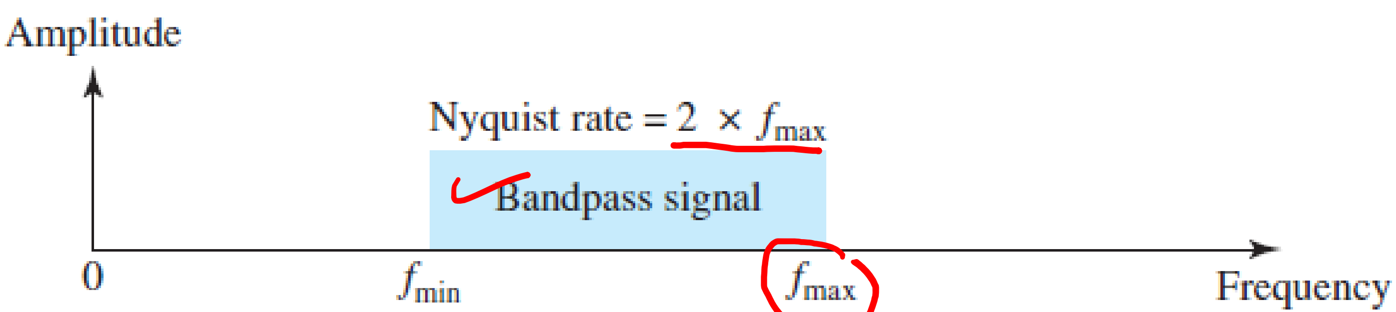
a. Ideal sampling b. Natural sampling c. Flat-top sampling

NYQUIST THEOREM FOR SAMPLING RATE

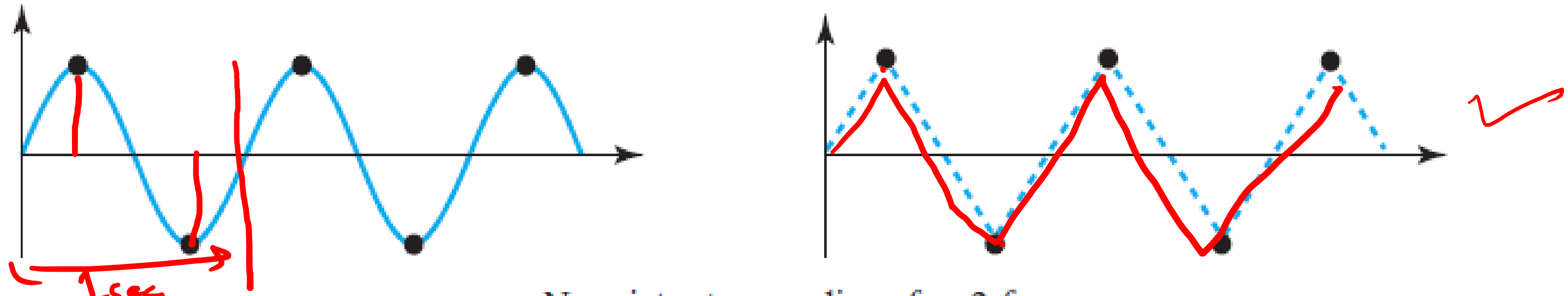
- According to the **Nyquist theorem,** to reproduce the original analog signal, one necessary condition is that the *sampling rate* be at least twice the highest frequency in the original signal.



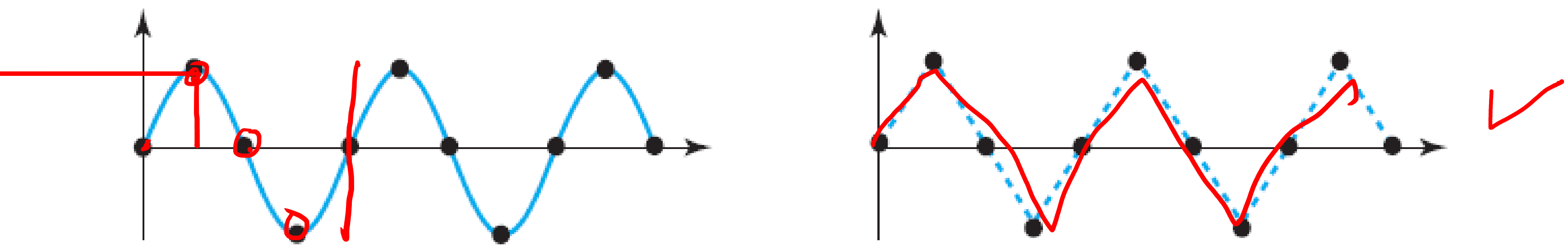
200 kHz



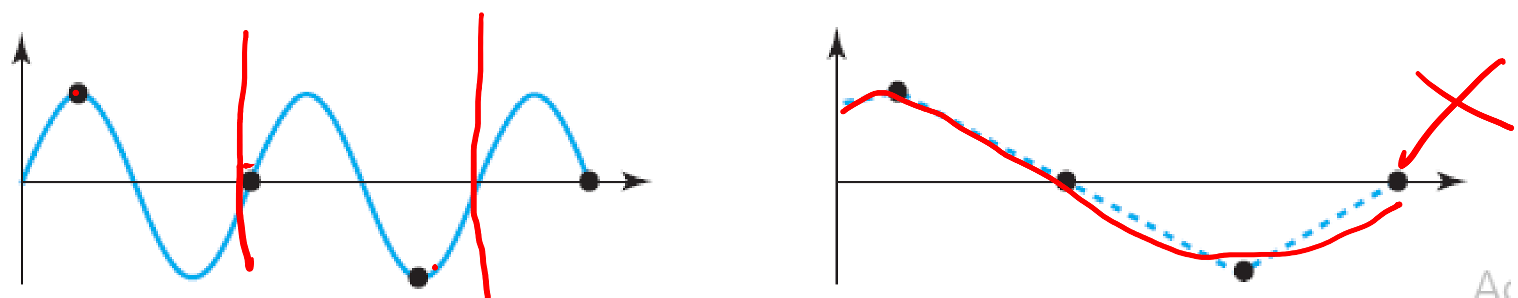
RECOVERY OF A SAMPLED SINE WAVE FOR DIFFERENT SAMPLING RATES



a. Nyquist rate sampling: $f_s = 2f$



b. Oversampling: $f_s = 4f$



c. Undersampling: $f_s = f$

QUANTIZATION

- The result of sampling is a series of pulses with amplitude values between the maximum and minimum amplitudes of the signal.
- The set of amplitudes can be infinite with nonintegral values between the two limits.
- These values cannot be used in the encoding process. The following are the steps in quantization:

EXAMPLE

- To approximate the value of the sample amplitude to the quantized values. As a simple example, assume that we have a sampled signal and the sample amplitudes are between −20 and +20 V.
- We decide to have eight levels ($L = 8$).
- This means that $\Delta = 5$ V.

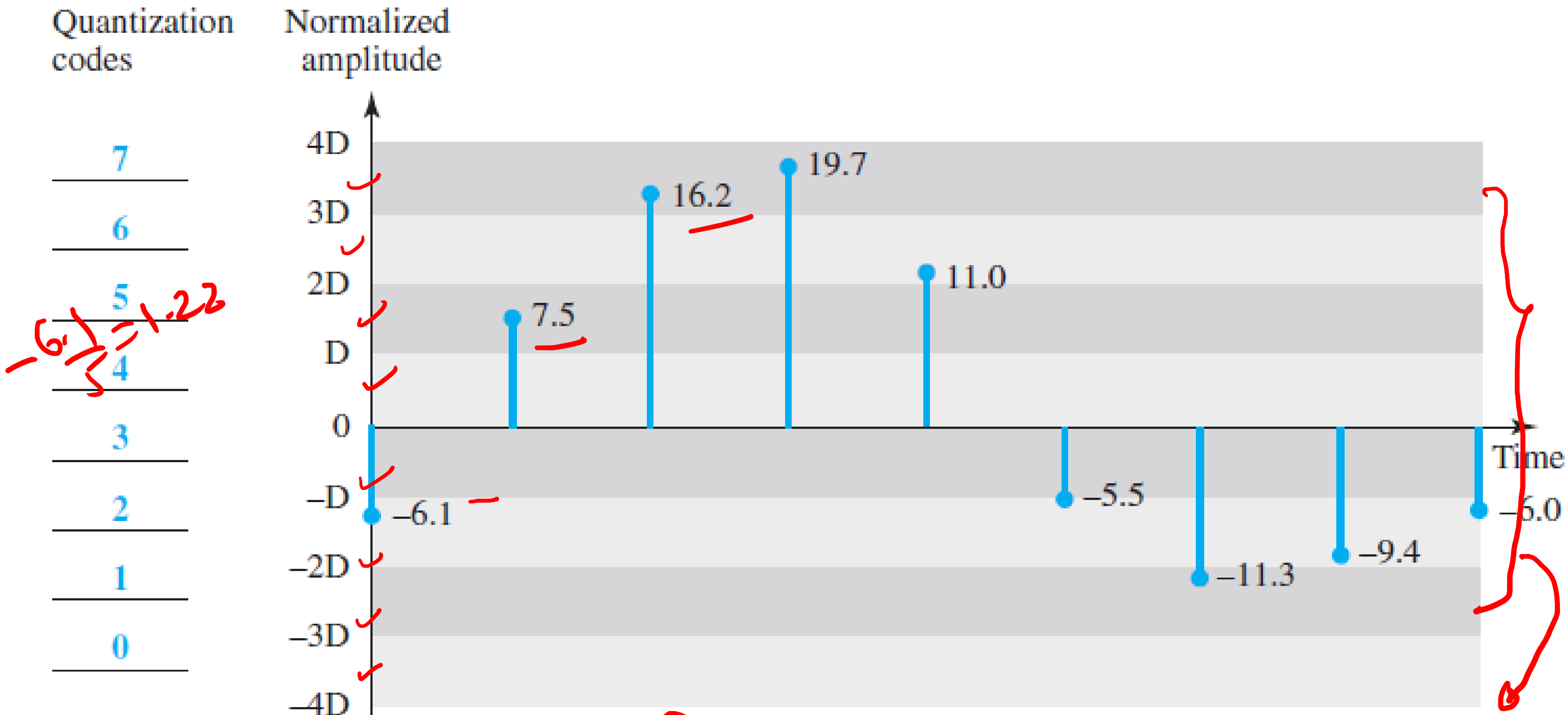
$\frac{-20 + (-20)}{8} =$ $\frac{-40}{8} = 1.51$

$\boxed{\Delta\ -5}$

+20

5V 0

−20



Normalized PAM values	–1.22	1.50	3.24	3.94	2.20	–1.10	–2.26	–1.88	–1.20
Normalized quantized values	–1.50	1.50	3.50	3.50	2.50	–1.50	–2.50	–1.50	–1.50
Normalized error	–0.38	0	+0.26	–0.44	+0.30	–0.40	–0.24	+0.38	–0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

QUANTIZATION LEVELS

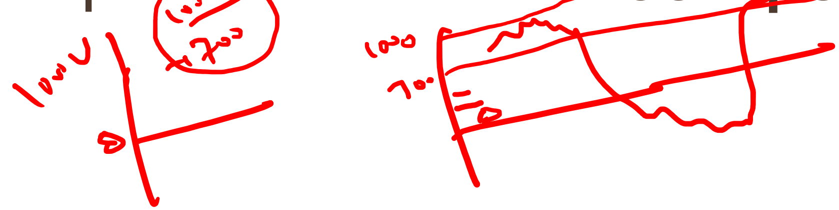
- In the previous example, we showed eight quantization levels. The choice of *L*, the number of levels, depends on the range of the amplitudes of the analog signal and how accurately we need to recover the signal.
- If the amplitude of a signal fluctuates between two values only, we need only two levels; if the signal, like voice, has many amplitude values, we need more quantization levels.
- In audio digitizing, *L* is normally chosen to be 256; in video it is normally thousands. Choosing lower values of *L* increases the quantization error if there is a lot of fluctuation in the signal

QUANTIZATION ERROR

- Quantization is an approximation process
- we have $-\Delta/2 \leq \text{error} \leq \Delta/2$.

UNIFORM VERSUS NONUNIFORM QUANTIZATION

- For many applications, the distribution of the instantaneous amplitudes in the analog signal is not uniform. Changes in amplitude often occur more frequently in the lower amplitudes than in the higher ones. For these types of applications it is better to use nonuniform zones. In other words, the height of Δ is not fixed; it is greater near the lower amplitudes and less near the higher amplitudes. Nonuniform quantization can also be achieved by using a process called **companding and expanding.**



BIT RATE

- The bit rate can be found from the formula
- Bit rate = sampling rate X number of bits per sample = f_s X n_b

EXAMPLE

- We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

Sampling rate = 4000 × 2 = 8000 samples/s

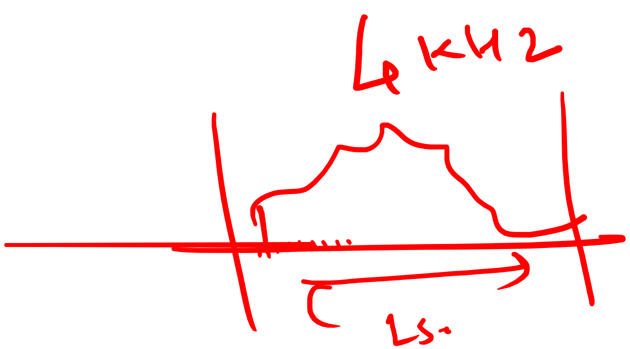
Bit rate = 8000 × 8 = 64,000 bps = 64 kbps

N.T → S.R = 2 * fmax

= 2*4000

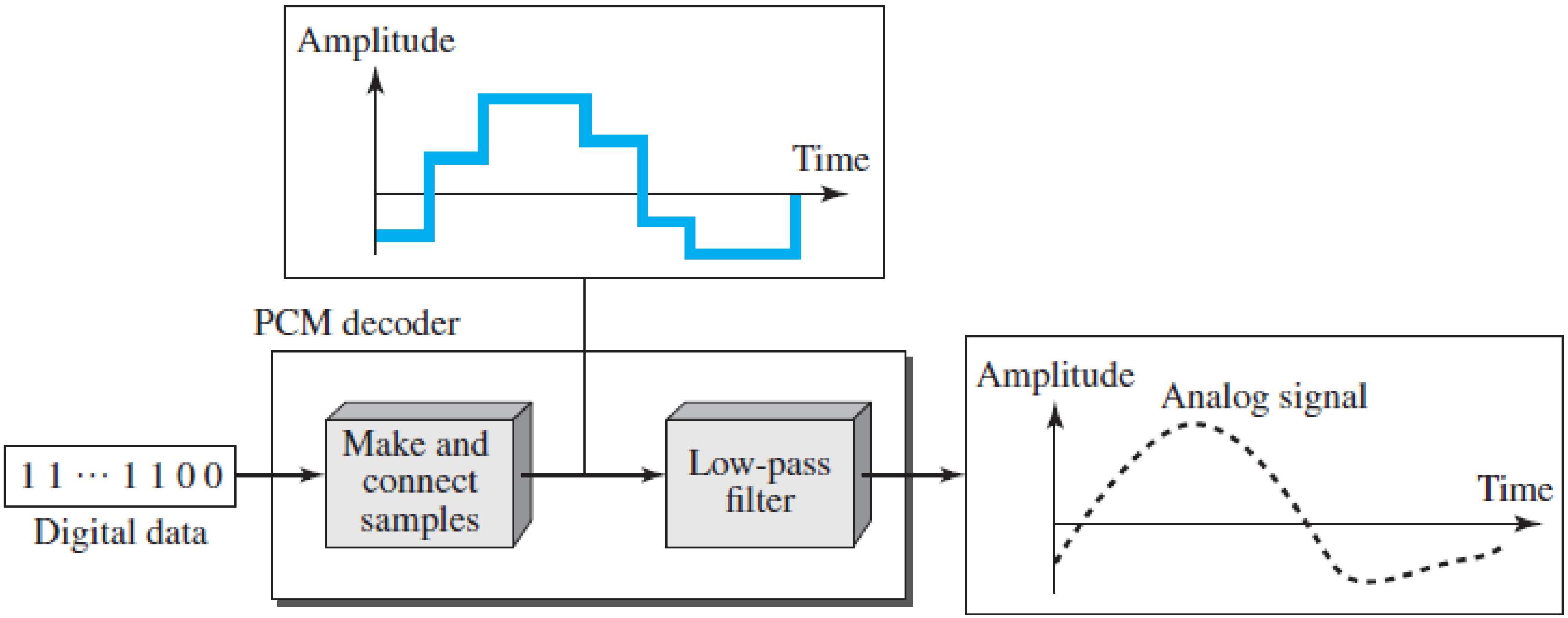
=

Sampl = 8000 samples



ORIGINAL SIGNAL RECOVERY

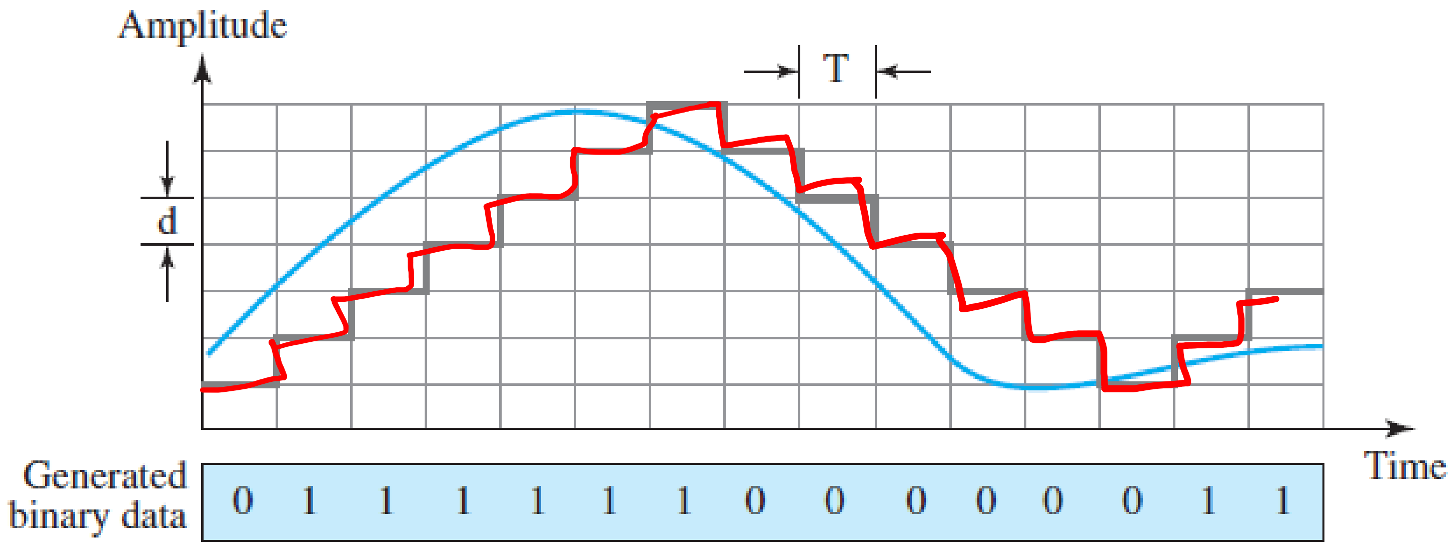
- It requires the PCM decoder



DELTA MODULATION

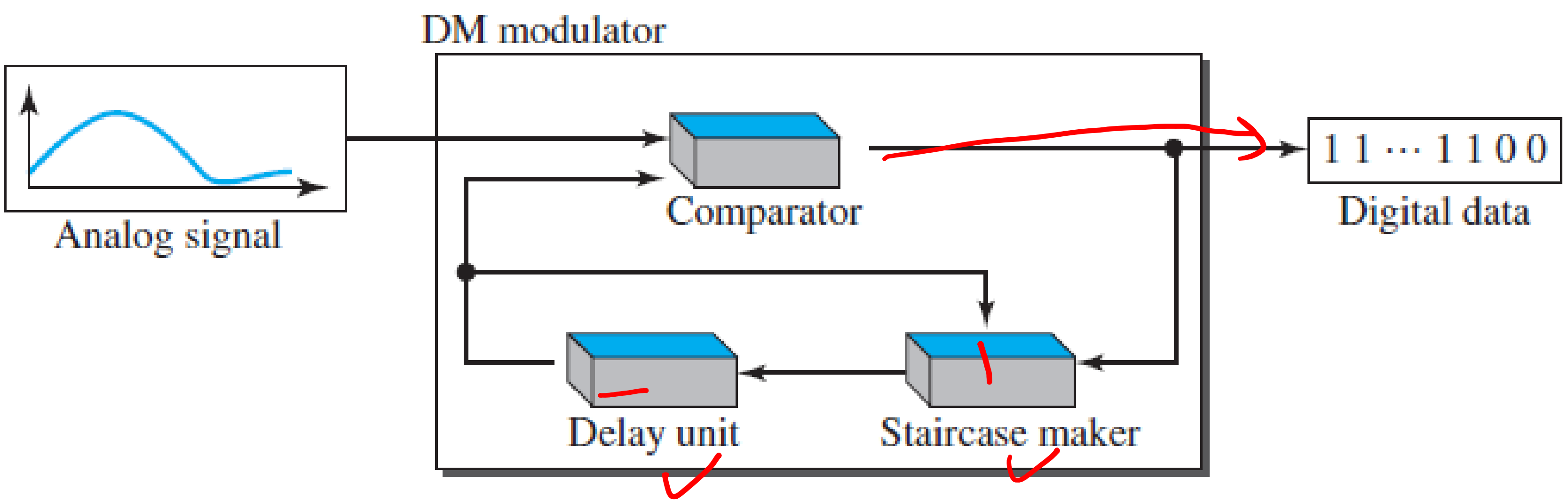
- PCM finds the value of the signal amplitude for each sample; DM finds the change from the previous sample.

The process of delta modulation

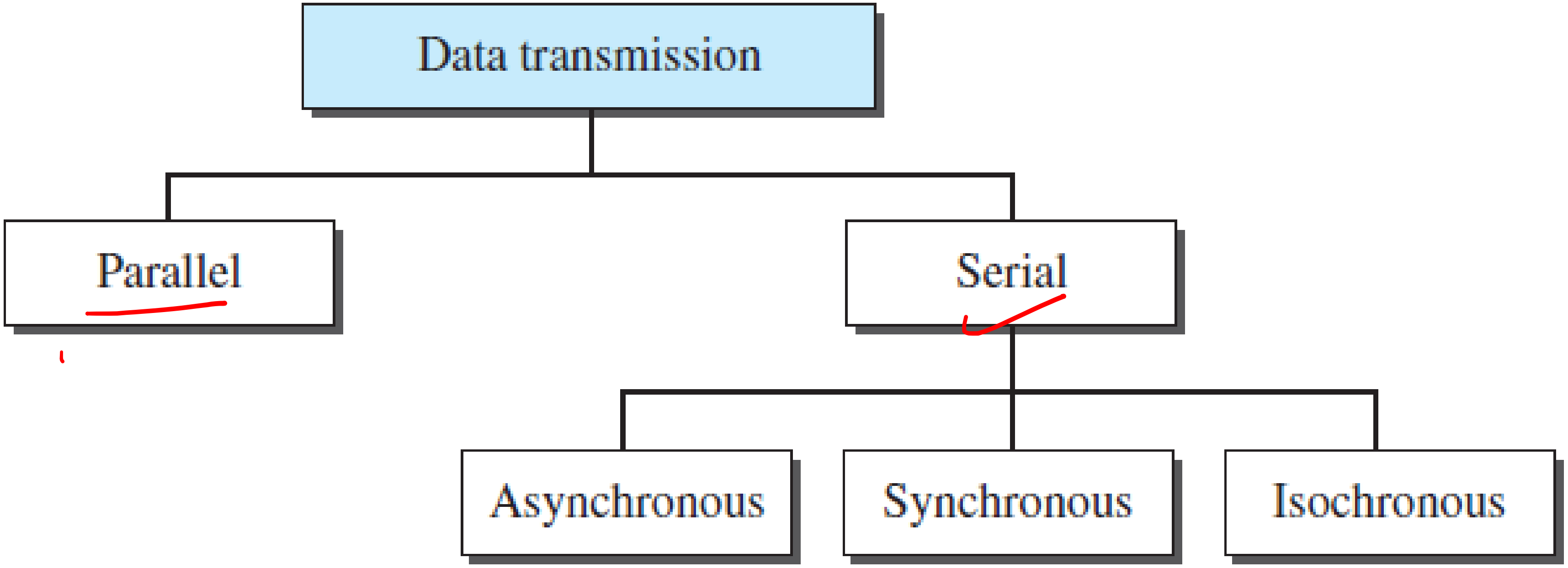


IMPLEMENTATION

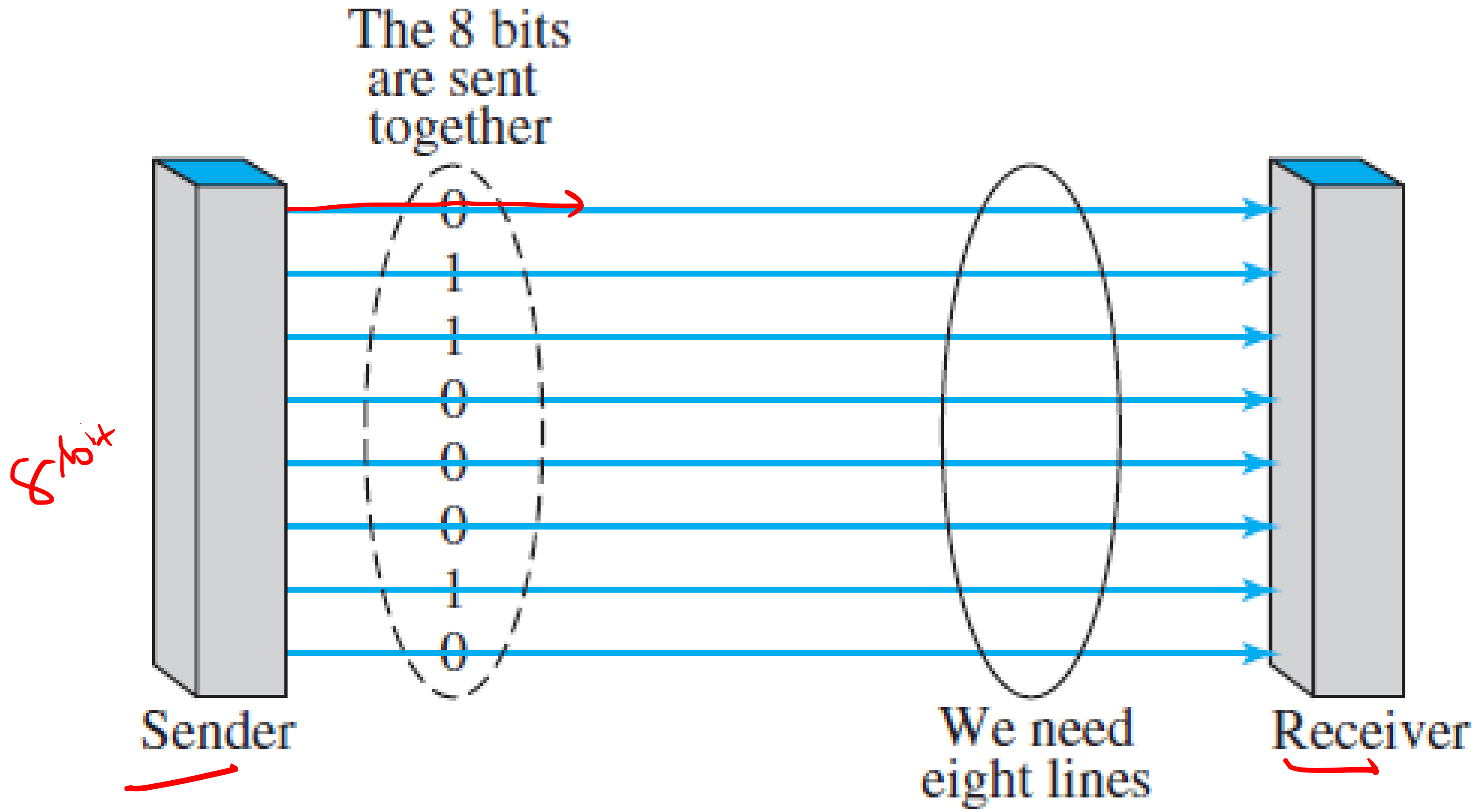
Delta modulation components



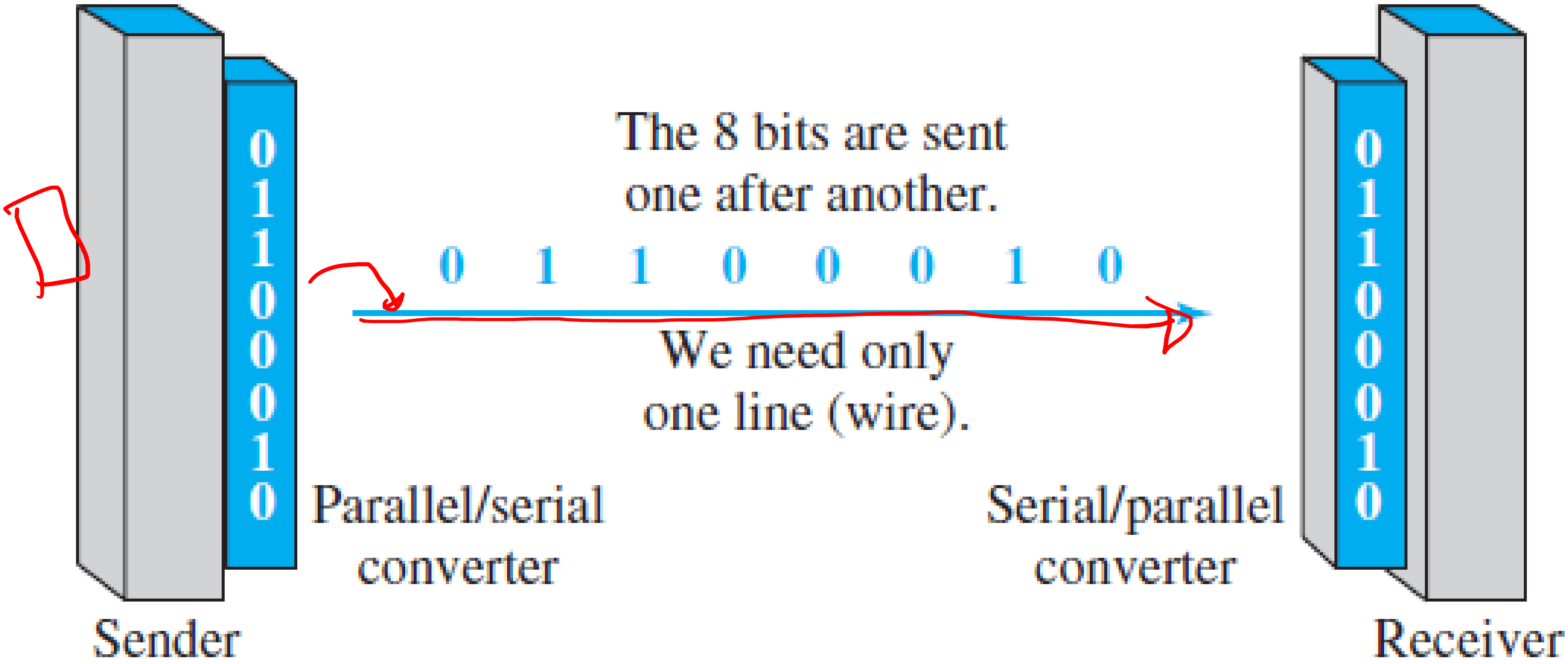
TRANSMISSION MODES



PARALLEL TRANSMISSION

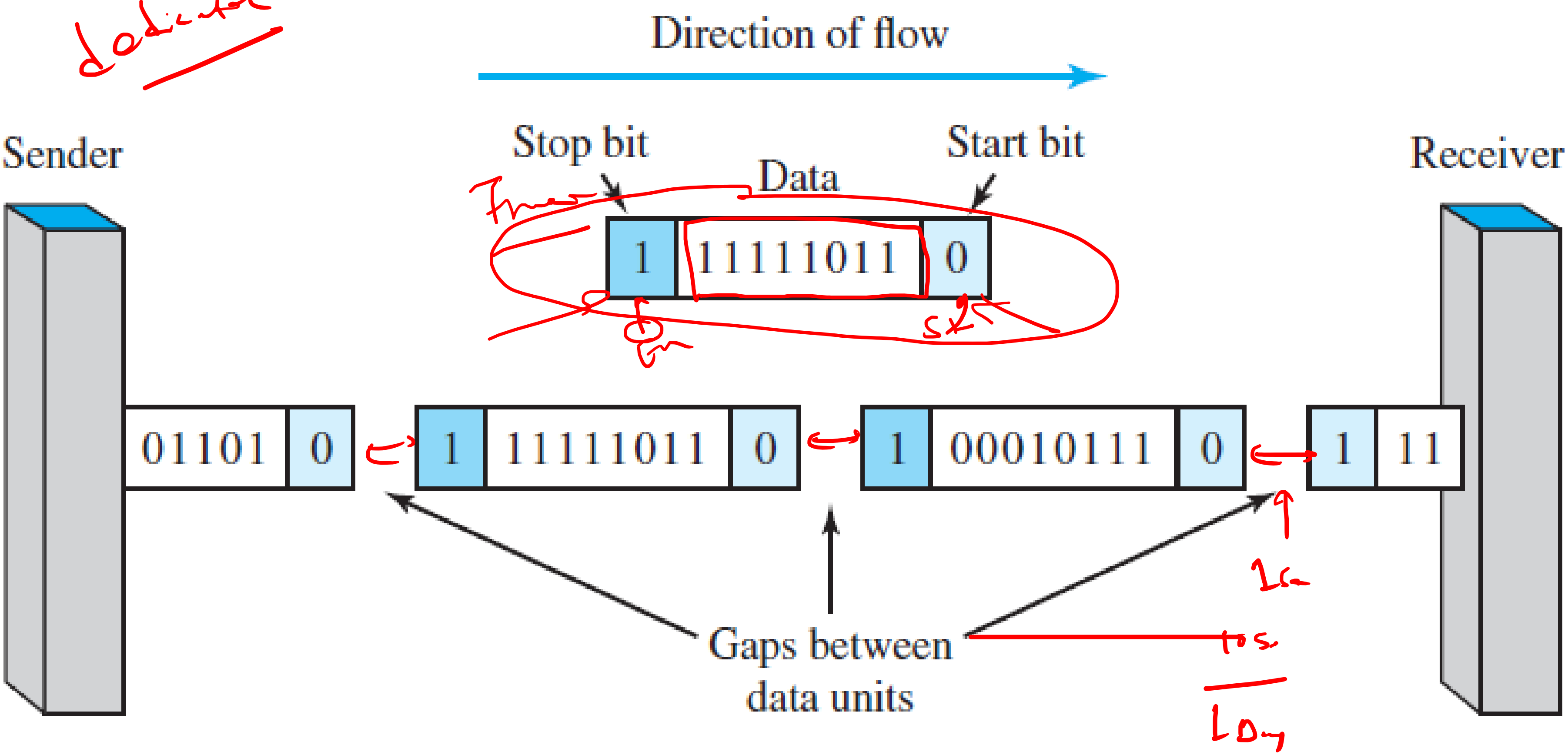


SERIAL TRANSMISSION

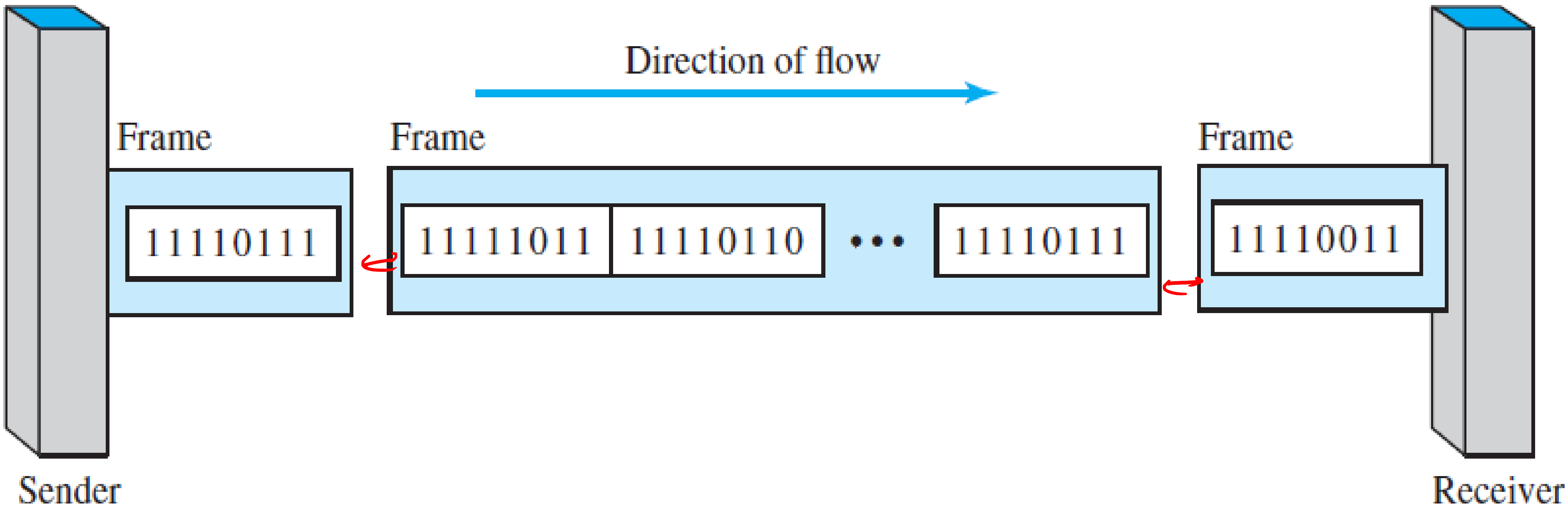


ASYNCHRONOUS TRANSMISSION

dedicated



SYNCHRONOUS TRANSMISSION



APPLICATIONS OF ENCODING TECHNIQUES

- Manchester encoding is used in Ethernet
- Differential Manchester is used in Token Ring LAN
- 4B/5B-NRZI encoding is used in FDDI LAN
- PCM is used in public switched telephone network

SUMMARY

- Thank you